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ORIGINAL ARTICLES.

The Petrography and Correlation of the Surface Deposits of South-east Devon.

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I. Introduction.

PRELIMINARY work on the Surface Deposits has been published (1); this research is a completion and revision of that paper. Many fresh localities have been examined and the Beach Deposits more thoroughly investigated.

The limestone plateaus are the most conspicuous feature in the scenery of the district. There are three levels near Torquay. One level is at 300 feet, bordering the Upton Valley; Wall's Hill is 260 feet high; but the majority are at the 200 ft. level. The soils on limestone afford conditions extremely favourable for the recognition of a foreign mineral assemblage, since these rocks yield a very small heavy residue (2). The actual thickness of soil present is very small, and very large samples must be taken to ensure an adequate concentrate.

Waldon Hill has yielded the best residue in mineral frequencies. This hill was formerly wooded, and now the highest portion, from which the samples were taken, is enclosed by a wall; both factors have operated in conserving the soil in an area much built over.

Samples were collected at numerous points on a plateau; these were panned fractionally, the residues were then mixed and again panned in order to separate the large quantities of silt. The panned material was then dried and sieved through a 50-mesh sieve, the calcite was removed by very dilute hydrochloric acid, and a separation made by redistilled bromoform.

Plateau deposits at similar heights, from Kingskerswell, Torbryan, Denbury, Churston, Berry Head, and near Mudstone Bay, were sampled for a comparison with the Torquay examples. Fissures occur in the limestone, filled with sand and soil; these were examined and also the soil from the tops of the Lower Devonian monadnocks above 300 feet.

At Aller Vale and Wolboro there are sands containing two lithological horizons like those at Little Haldon. There is a layer of sand and greensand at the base, and an upper horizon with a brownish clayey matrix containing many flints. The lower is Cretaceous in lithological characters and the upper is Eocene. They are not distinguishable in hand-specimens from the deposits on the Haldons. Typical residues were also obtained from the latter locality in order to institute a comparison with the Plateau Deposits.

Raised beaches occur at Hope's Nose and on the Thatcher rock, with traces at Galmpton Point. The first is at 25 feet above high water mark, that on the Thatcher at 15 feet. They both rest on limestone and are mainly sandy with some pebbles at the base. Fossils belonging to recent species have been obtained at both localities.

Kent's Cavern contains the following deposits in downward succession: black mould, granular stalagmite, a black band, cave earth, crystalline stalagmite, and breccia. Of these the cave earth and the breccia have been examined.

Alluvium from the Anstey's Cove and Ilsham Valleys has been investigated, and samples have been taken from all the beaches in Torbay that have material fine enough for separation. The mineral types from the Start metamorphic rocks were also examined in a sample of sand collected from the south end of Hallsands Beach.

II. PETROGRAPHY.

A. *The Plateau Deposits.*

The minerals obtained from twenty separations were:—

Garnet
Magnetite

Anatase
Rutile
Zircon

Andalusite
Barytes
Brookite
Staurolite

Apatite
Calcite
Corundum
Ilmenite
Haematite
Quartz
Tourmaline

Augite
Biotite
Chlorite
Epidote
Hornblende
Muscovite
Sphene

Kyanite

Leucoxene
Limonite

Quartz forms the main constituent of the panned material. Its inclusions are mainly of the irregular type. Perfect crystals from the limestones are also present. Minute chert fragments have been identified.

Muscovite is biaxial with a large optic axial angle. Inclusions are numerous, some of the rutile needles being quite large. The flakes are often nearly hexagonal. The greatest quantity has been obtained from Waldon Hill and Daddy Hole. It is probable that the mineral would be easily washed out of the soils.

Anatase is colourless, deep yellow or light indigo. In shape the crystals are nearly perfect, with the (001) face well developed, or half crystals with the same face prominent. Some of these half crystals are found attached to ilmenite.

Andalusite is not generally pleochroic, but such fragments are found. The grains are angular, a few have dark inclusions. One grain of chiastolite was found in the Eocene residue from Aller Vale.

Apatite forms angular to rounded grains, clear, or yellowish to brownish with dark inclusions.

Augite is extremely common in the Daison and Ilsham concentrates, and occurs in most of the others. It forms brownish platy fragments with conspicuous cracks. One perfect grain from Brixham showed the forms (100), (010), (110), $(\bar{1}11)$.

Corundum occurs in wedge-shaped grains; the royal blue colour is patchy with blue pleochroism. It is dark with many inclusions.

Epidote comes from Waldon Hill and Kingskerswell only. It is colourless to greenish with dark inclusions.

Garnet is either slightly yellow or pinkish-brown. The grains are rounded and are all isotropic.

Hornblende is greenish or brownish, in small wisps; it is very scarce.

Kyanite is sporadic in occurrence. The character is that of "Greensand" kyanite in elongated prisms (100) and (001), with the (010) cleavage prominent. Some grains have slightly ragged ends, and small grains show signs of solution, the re-entrants showing a tendency to disappear.

Rutile is dark foxy-red and may attain ·3 mm. in size. A few large yellow crystals, with anomalous figures, are probably secondary.

Sphene occurs as well-rounded grains or as wedges, with re-entrants. The double refraction is orange-red to deep indigo. The grains commonly give a good directions-figure with a biaxial optic angle of about 30 degrees.

Staurolite of the Permian type with indented edges occurs, but by far the greater part consists of larger grains up to ·4 mm., and with more colour than in the Permian examples. These are without conspicuous re-entrants. The amount varies considerably, but the Waldon Hill concentrates contain a fair quantity.

Topaz forms clear, transparent plates, dark inclusions are few. The edges are much fractured. The directions-figure may be completely biaxial, or give a single arm which does not coincide with a cross-wire.

Tourmaline is the most abundant mineral. The colour range is considerable; brown, blue, green, violet-grey, purple, nearly colourless, and zoned grains have been noted. The shapes are either angular, or broken and striated prisms; basal flakes giving a complete figure occur.

Zircon is of three types; rounded grains, often dark; short, clear, stumpy crystals, sometimes pinkish; euhedral prisms with many zoned inclusions. Biaxial grains are not uncommon.

The mineral residues are characterized by large quantities of tourmaline and zircon. Andalusite, topaz, and rutile occur in fair amount. Garnet is usually present and about equal in frequency to the andalusite. Kyanite is generally present, but not in any force in any one slide. Epidote, sphene, and corundum are sporadic, and occur as a few grains only. Augite is usually present and may occur in quantity; muscovite and apatite are constant in occurrence.

Other plateau deposits at a distance from Torquay agree well with the type residues, except that from Torbryan, which is very fine-grained and garnets are numerous.

The residues from above 300 feet contained none of the characteristic minerals, such as kyanite, and differed from the residues obtained from the Devonian rocks only in the presence of a little augite.

The Aller Vale sands are of two types, of which the lower yielded a concentrate like that from the Cretaceous of Little Haldon, except that the frequency of staurolite and kyanite was about half that from the Haldons. The higher sands gave a residue largely consisting of tourmaline with a small frequency from the other species. The Wolboro sands were similar to these.

The material from the fissures in the limestones gave a residue similar to that from the plateaus; pleochroic andalusite occurs in a fissure at Wall's Hill.

The general character of the more abundant residues is like that from the Cretaceous and Eocene from the Haldon Hills (4). Points of difference are the less frequency of kyanite, andalusite, and staurolite, factors with which the Aller Vale sands agree. Garnets and apatite are more common in the Plateau materials. The latter differ from the Pliocene of Cornwall in the less amounts of andalusite, topaz, kyanite, and staurolite (6).

B. *The Beach Deposits.*

The minerals were obtained from twenty samples and included :—

Garnet
Magnetite
Pyrites

Anatase
Rutile
Zircon

Andalusite
Staurolite
Topaz

Apatite
Calcite
Haematite
Ilmenite
Quartz
Tourmaline

Augite
Biotite
Chlorite
Epidote
Hornblende
Muscovite
Sphene

Albite
Microcline
Kyanite

Glauconite
Leucoxene
Limonite

These include samples from dredgings and from cemented " head ".

A description of these minerals would be largely a repetition of that given for the Plateau species, hence a few only will be detailed.

Epidote, either clear plates or half opaque. This opacity may be due to dark inclusions, but in some the grain is rounded and the surface etched The interference colours are brilliant carmines and greens. Pleochroism is apparent in the greenish grains. The directions-figure is commonly a complete biaxial figure with large angle, but compass figures are sometimes obtained.

Garnet: There is a greater proportion of brownish-pink rounded fragments, the rest is nearly colourless to yellow. It is isotropic. Some garnets with dodecahedral cleavage similar to those from the Culm were noticed (2).

The distribution is as follows :—

(*a*) The raised beaches yield residues slightly different. Hope's Nose raised beach gives a greater proportion of heavy residue; kyanite, garnet, and staurolite are common, and in greater frequency than in the Plateau Deposits. Kyanite is absent from the Thatcher locality, but staurolite and garnet are still common. There is a greater amount of epidote and sphene from the Thatcher Rock. Topaz is less frequent than in the Plateau residues.

(*b*) The Kent's Cavern breccia derived its material from the Devonian only; the cave earth contains species similar to those on the plateaus. It differs from the raised beaches in less relative amounts and in the rarity of andalusite. The alluvial deposits were uninteresting.

(*c*) The modern beaches give residues of types illustrating the local character of the materials. South of Goodrington the minerals are entirely local in origin; north of it other materials are present in small amount. Kyanite, andalusite, and topaz are recorded from single grains only. Epidote is the only mineral with a wide distribution round the Bay.

The concentrate, illustrative of the Start metamorphic detritus, obtained from Hallsands, contained these minerals in order of frequency: epidote, garnet, apatite, chlorite, sphene, and hornblende. The small amount of hornblende is to be noted. Tourmaline occurs in quantity.

The cemented "head" contains materials similar to those from the heads of the beaches, where the minerals are derived entirely from the rocks near at hand.

(*d*) Dredgings were taken from depths of 45 feet, off Black Head and north of Petit Tor. The former contains epidote and augite as abundant constituents; augite was not found further north, but the epidote was more abundant. Apatite is common and garnet occurs, but in nothing like such quantity as in the raised beaches. Rare andalusite and topaz were recorded. These deposits differ from the modern beaches in the much greater frequency of the transparent minerals of the heavy residue. Calcite constitutes 10–15 per cent of the silt.

III. SOURCES OF ORIGIN OF THE MATERIALS.

A. *The Plateau Deposits.*

Most of the minerals are derived from rocks within the area of South Devon. Granite and its contact rocks yield andalusite, biotite, and other species. But there are no doubly refracting garnets like the Dartmoor examples. Dolerite intrusions, of which there are many in the neighbourhood, might have supplied apatite, augite, epidote, and hornblende. The Start rocks contains these minerals and also the sphene is like the Start type; further, the fair amount of isotropic garnet came from this source. Sedimentary rocks near by have staurolite and apatite, and rarer epidote and sphene to contribute to these deposits. Permian derived staurolite occurs, but the main amount is in larger crystals and is not chipped into re-entrants. This staurolite and the kyanite must have come from further afield. They diminish in amount when the Cretaceous is traced from the Haldon Hills to Aller Vale. This agrees with the fact that kyanite is more abundant on Blackdown; therefore a northern origin for these minerals is strongly indicated (4, 5, 6), in addition to supply from Armorica.

B. *The Beaches.*

The coarse materials in the raised beaches are all of local rocks. The finer constituents are of two categories. That from rocks in the neighbourhood consists of epidote and apatite; the scarcity of augite is remarkable. These minerals were supplied by the Black Head dolerite. The other minerals are the characteristic species of the Plateau deposits. But these last do not contain sufficient garnet, staurolite, and kyanite in their present condition to account for the greater frequency of these minerals in the raised beaches. The source of the garnet may be sought in the Start rocks and some from the Culm. For the others, two alternatives present themselves—either the Armorican rocks were supplying great quantities of detritus, which it is difficult to believe, since the configuration of the coast was not very much different from that at the present day, and now Armorican material does not figure in the list from the dredgings. The other alternative is that Cretaceous and Eocene material had a former great thickness and extension on the plateaus above the coast; and also out at sea, as evidenced by the concentrate from Hallsands.

The study of the modern beach deposits has emphasized the fact that the heads of the beaches contain only material derived from the rocks at the heads of these beaches. The raised beaches are banked against limestone and could never have extended inland more than a few yards. These considerations show that the coast adjacent to the raised beaches was covered by a considerable thickness of Plateau Deposits when they were being formed.

The Kent's Cavern breccia derived its materials from the limestones, grit, and slate in the neighbourhood, all being Devonian. The cave earth derived its heavy minerals from the Plateau Deposits.

The beaches contain zircon, tourmaline, and the usual opaque species with some muscovite and apatite; all these are derived from the rocks at the head of the beaches. Epidote is the only mineral that is distributed against the tidal current, perhaps because of its flattened form, since the rounded sphene is not carried with it.

Epidote and augite form the large proportion of the sea bottom residues and are obviously derived from Black Head. Augite does not travel as far as the epidote.

The concentrate from the Start contains, in addition to the metamorphic minerals, large amounts of tourmaline, and a little kyanite, staurolite, and andalusite. The pebbles along this great deposit of Slapton Sands are nearly exclusively composed of flint. These facts point to the existence of Cretaceous or Eocene deposits on the sea floor near by.

Quartzite pebbles, containing garnet and staurolite, and hence not of the early Permian type, are widely distributed on the beaches to the east of the Bay; Shennell Cove is their approximate limit in Torbay. These are suggestive of Triassic deposits off the mouth of Torbay.

IV. GEOGRAPHICAL CONSIDERATIONS.

In Cretaceous times there was a great transgression of the sea and these deposits were laid down over the greater part of England. Near by, the Haldon Hills still retain these sediments, and it will be suggested that the plateaus on the limestones in South Devon were initiated at this period.

The differences between the samples from the Plateau Deposits and those from the Haldons may be summed up as (4):—

(*a*) The amount of andalusite is half that in either the Cretaceous or Eocene.

(*b*) Kyanite and staurolite have the same frequency as that in the Eocene, and in the Cretaceous of Aller Vale.

(*c*) Topaz is equal in amount to that in the Cretaceous and much less than that in the Eocene.

The Cretaceous of Aller Vale differs from that of the Haldons in the less frequency of staurolite and kyanite, and a northern origin s indicated for these minerals; the Eocene at this locality is much poorer in the transparent minerals.

The equality of frequency of the topaz in the plateau samples with that in the Cretaceous of the Haldons is correlated with the diminished amounts of staurolite and kyanite in the Cretaceous of Aller Vale to indicate that the plateau deposits are of Cretaceous rather than of Eocene date. It follows that Eocene deposits were also present when the nearness of the Eocene at Aller Vale is considered.

Jukes-Browne has made a study of the physiography of the area, and has deduced that the drainage was initiated on a thick cover of sediments on the plateau. He suggested that the age of the planation was Eocene (7).

The heights above the plateau formed islands, and the poor grading of the Haldon sediments shows that they were nearer land; the eastern flanks of Dartmoor were the source of the Chalk material. The Upper Chalk was eroded during the deposition of the Eocene; *Micraster cor-anguinum* and *Marsupites* have been found in the Wolboro and Aller Vale pits.

The differences in levels between the Haldons at 800 feet and the limestone plateaus is correlated with the faulting which formed the Bovey depression. During its formation the Cretaceous and Eocene were removed and the Palaeozoic floor uncovered (8). This amount of erosion gives an explanation of the removal of some of the material from off the plateaus. Faulting continued later, and accounts for the differences in level in the detached areas of the plateaus.

Plateaus at 1,000 feet and 800 feet are developed near Dartmoor, and have been dated as Pliocene by the Survey (8, 9). This has not been universally accepted; no evidence was deduced from detritals, and further the Cretaceous Haldon platform is at 800 feet. But the in-fall of the Bovey trough prevents a correlation of the two platforms at 800 feet, without mineral evidence.

The 400 ft. platform in South Devon contains no Pliocene residues, and therefore is not comparable with that platform in Cornwall.

In considering the possible Pliocene age for the formation of the plateaus, the presence of kyanite in small amounts is important. That mineral is abundant in the Cornish Pliocene, except at St. Keverne; it is absent from the latter locality. If Pliocene currents were not carrying kyanite to St. Keverne from Armorica, one would expect it to be absent from further up the supposed Channel river (6). Derivation of the kyanite in the plateaus from the north, as suggested, implies that a strait existed on the east of Dartmoor; if such were the case, then St. Keverne should have received kyanite-bearing currents from this direction, supposing the Plateau Deposits to be Pliocene. Hence the southern Cornish Pliocene cannot be contemporaneous with these deposits. Other considerations of physiography (7), and the frequency of staurolite, kyanite, and andalusite indicate that the plateaus were not formed in the Pliocene period.

The two raised beaches investigated are of slightly different date, and the lower level of the Thatcher beach is not due to faulting. At this later time Black Head was more opened up by erosion, and there was less material on the plateaus, since the Thatcher concentrate contains a less proportion of transparent minerals.

Hence the raised beaches represent two different levels of emergence of the land, and indicate that this movement was prolonged.

The comparatively rapid waste of the land formerly in Torbay, compared with the less rapid loss of land near Hope's Nose, is due to the fact that the cover of limestones in the Bay was very thin, or had previously been faulted down. The sea made rapid progress in the Permian deposits.

V. SUMMARY OF THE CONCLUSIONS.

The petrography of the Plateau Deposits has been determined. They yield species both of local origin and of the general Haldon types.

The kyanite and staurolite present have been derived from the north.

The planation of the limestones was initiated during the Cretaceous period.

The raised beaches are of slightly different types, the Thatcher raised beach being later. They furnish evidence of a former greater thickness of the Plateau Deposits.

Modern beach deposits furnish some evidence of the distributive powers of certain minerals, and point to the existence of Triassic and Cretaceous sediments outside the Bay.

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(8) W. A. E. USSHER, "Geology of Newton Abbot," *Surv. Mem.*, 1913.
(9) C. REID and others, "Geology of Dartmoor," *Surv. Mem.*, 1912.

On *Cyamocephalus*, a new Synxiphosuran from the Upper Silurian of Lesmahago, Lanarkshire.

By the late L. D. CURRIE, B.Sc., Research Student, Glasgow University.

THE Upper Silurian rocks of Lesmahago, Lanarkshire, have long been known to contain Arthropod remains. In the Kelvingrove Museum, Glasgow, are a number of curious forms from the Logan Water Lesmahago, which Professor McNair was good enough to allow me to examine. In the hope of solving some problems presented by them, I obtained, through the kindness of the Keeper of the Geological Department of the British Museum, the loan of a specimen from the same locality, which forms the subject of this note. Instead, however, of solving any difficulties, the specimen presented a new problem.

The rock in which the specimen is preserved is an irregularly fissile siltstone, or sandy mudstone, identical in appearance and also in thin section with that in which those curious forms are found, and probably from the same horizon, viz. the *Ceratiocaris* beds and Ludlow fish band, i.e. Lower Ludlow.

Unfortunately the beds which have yielded these specimens are now largely covered by quantities of scree, and further work would entail extensive quarrying.

Genus CYAMOCEPHALUS[1] gen. nov.

Characters as in description of species. I have ventured to create this genus for the reception of the single form, viz. :—

CYAMOCEPHALUS LOGANENSIS sp. nov.

This species is represented by the dorsal surface of an individual, both as a cast, and as a hollow mould, which, being imperfectly preserved, leave much to be yet ascertained as regards the exact structure.

Holotype.—British Museum (Natural History), Reg. No. I. 16521.

Description of Species.

Prosoma.—The prosoma is heart or bean-shaped. The anterior margin is ovate and smooth, and the posterior border is concave, curving strongly inwards near the centre, and backwards towards the posterior lateral margins which are rounded. A portion of the left postero-lateral margin is not preserved, giving the outline of the prosoma a slightly asymmetrical appearance.

The length of the prosoma along the mid-line is 19 mm., while the lateral portions extend 8 mm. farther posteriorly, making the total length about 27 mm. The greatest breadth, which is at the level of the median posterior margin, is about 26 mm.

The anterior and antero-lateral margins of the prosoma are bounded by a border about 1 mm. in width and with a finely reticulate ornamentation. The postero-lateral margins are more faintly preserved and the border quite indistinct, but the posterior margin shows a similar doublure.

As has already been mentioned, the specimen is imperfectly preserved, and unfortunately the structure of the prosoma is not clearly enough shown to be accurately described There is no trace of an axial portion or glabella. Near the left anterior margin, however, is a semilunar elevation, the surface of which appears to be faceted, and may represent a compound lateral eye, although

[1] *Cyamo* from *kuamos* (Gk.), a bean.

not a very well developed one. There is also a groove extending from the left lateral margin of the prosoma in front of the genal angle (about one-third of its length from the posterior end) and running inwards and forwards and cutting the anterior margin. On the opposite side there is no corresponding eye or facial suture preserved.

Abdomen.—The abdomen consists apparently of ten segments, of which the first six are probably free and are well separated from one another. They are more clearly seen at the front end, where they are markedly convex anteriorly. The body is only slightly trilobed, the axis broad, and scarcely distinguished from the pleurae, only a slight indentation marking the boundary. The width of the axis in the front part of the abdomen is about 14 mm. In the hinder part the boundaries of the axis are too indefinite to be measured accurately, but it appears to decrease slightly from about 14 mm. in segment II, to about 11 mm. in segment VI. The average length of the anterior segments is about 4 mm., the lengths being approximately as follows :—

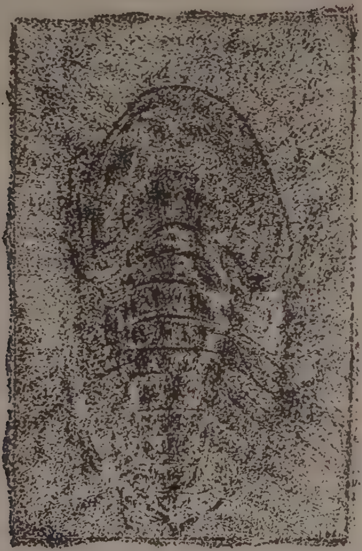

Fig. 1.—*Cyamocephalus loganensis* sp.n. Drawing of cast (natural size).

Segment	I	about	4·0 mm.
,,	II	,,	3·5 mm.
,,	III	,,	4·0 mm.
,,	IV	,,	4·0 mm.
,,	V	,,	8·5 mm.
,,	VI		

Behind segment VI the segments of the axis are shorter, being about 3·25 mm. long, not well separated from each other, and quite straight. The axis extends nearly to the posterior tip and consists of probably other four segments. It measures approximately 13·5 mm. in length, and tapers from about 11 mm. in segment VI, to about 4 mm. in segment X.

Although obviously present as flat lateral areas on each side of the axis, the pleurae are extremely faintly preserved, none being sufficiently clear for accurate description. In segments IV and V, however, the pleurae on the right side are moderately distinct, and show the general shape. From the boundary of the axis they bend back posteriorly at an angle of about 60 degrees, and are rounded at their ends. There appears to be also a narrow longitudinal groove which bisects the pleurae and disappears inwards towards the axis.

Posteriorly, the lateral portions are very indistinct, but the posterior margin is pointed and is bounded by a narrow border. There is some indication that the posterior margin was prolonged backwards, perhaps into a spine, but the specimen has been trimmed so close to the fossil, that one cannot be sure.

? *Appendages.*—Around the margins of the body are curious obscure markings which suggest appendages, but which may be merely radial grooves or corrugations in the siltstone. They are also visible within the body itself, and if appendages would indicate the extremely thin nature of the carapace. At the posterior end they point obliquely backwards, while anteriorly they are directed more or less obliquely forwards; and between these two extremes intermediate positions occur. A point against their being appendages is their remarkable length. They seem to extend right out to the edges of the specimen, and probably continued farther, but have been cut off in the trimming of the rock.

Conclusion.—The systematic position of *Cyamocephalus* is not quite clear. At first sight, its appearance suggested Trilobite affinities, but a resemblance to the Hemiaspidae (e.g. *Bunodes*) was pointed out by Professor Gregory, and consideration of this suggestion shows that the affinities of the present specimen are more probably with the Synxiphosura than with the Trilobita. A certain resemblance to the Trilobites is a feature of some other members of this order also. In the free segments of the abdomen, and the flat extended pleurae, the specimen agrees with the order Synxiphosura. The occurrence of compound lateral eyes and facial sutures is not confined to the Trilobita alone, but is well seen in such a form as *Neolimulus*[1]; while the absence of any definite glabella might favour the Synxiphosura, which have "a median portion more or less distinctly defined". Due to the close trimming of the specimen, any telson of the Synxiphosurous type is of course not observed; and yet there is some indication that the pointed posterior region was continued beyond the edge of the rock.

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[1] H. Woodward, Geol. Mag., V, 1868, p. 1.

Professor A. S. Packard proposed the name Synxiphosura for a number of interesting forms which appear to be Merostomata, but not true Xiphosura. He states[1] that "they serve, on the one hand, to connect the Xiphosura with the Eurypterida and also strongly suggest the community of origin of the Merostomata and the Trilobita". The Synxiphosura were divided by Packard into families, with one of which, the Bunodidae, *Cyamocephalus* seems to agree—"Head rounded; no genal spine; abdomen divided into a 'thorax' consisting of six Trilobite-like segments with diagonal pleural lines: 'abdomen' of four segments, besides the large telson (*Bunodes* and *Exapinurus*)."

Professor von Zittel united all the members of the group, together with certain genera of the Xiphosura, in the family Hemiaspidae, and according to the prevailing modern opinion this term is retained with the exclusion of the Xiphosurous forms and the Cambrian *Aglaspis*.

Its Synxiphosurous affinities, I think, warrant the inclusion of *Cyamocephalus* in that order; and until further specimens of this interesting form are found, showing better the details of structure, it must be placed provisionally in the family Hemiaspidae. And of the members of this heterogeneous family, it appears to be nearest *Bunodes*.

I desire to express my indebtedness to the Keeper of the Geological Department of the British Museum for allowing me to study this interesting specimen and to thank Professor J. W. Gregory for much helpful advice and criticism.

The Post-Glacial Erosion Theory of Drumlins.

By Professor J. Kaye Charlesworth, D.Sc., Ph.D.

In recent years Professor J. W. Gregory has challenged, one after the other, our most cherished beliefs and creeds in the field of glacial geology, fearlessly raising again the discarded standards, dust-laden these many years; the gaping fissures of the fjords, the glacial submergence, the residual character of many moraines, eskers, and kames, including the beautiful York moraines, and now[2]—the post-glacial origin of drumlins.

This view, that drumlins have been carved out of a sheet of boulder-clay by the action of wind and rain in post-glacial time, was advocated by a number of earlier writers, e.g. W. Harte,[3] and N. S. Shaler,[4] but was abandoned by later geologists for several

[1] *Mem. Nat. Acad. Sci. Washington*, iii, 1884, p. 151.

[2] *Trans. Roy. Soc. Edinb.*, liv (1926), p. 433.

[3] *Journ. Roy. Geol. Soc. Ireland*, ii (1867), p. 30.

[4] *Proc. Boston Soc. Nat. Hist.*, xi (1870), p. 27.

good and sound reasons to which, with increasing knowledge, equally good ones have been subsequently added. Though it is the purpose of this short note to consider these, it is not intended, except incidentally, to discuss the origin of these features, which is reserved for a future occasion, but to deal only with the one definite point raised in Professor Gregory's paper, namely that drumlins, apart from the stuff of which they are built, have no connexion with glaciation.

The most startling conclusion perhaps of Professor Gregory's studies is the one that drumlins lie, more often than not, oblique to the lines of ice-flow. The most hasty perusal of glacial literature, however, would suffice to show that this is a generalization without any justification in fact; for every statement to that effect which might be carefully combed out of published descriptions I am satisfied a score, probably a hundred, could be cited to the contrary. Everywhere where I have mapped them in recent years, in Donegal and the adjacent counties of north-west Ireland, in Armagh, Down, and Kerry, in Galloway, Carrick, and Kintyre, they have invariably been found to be parallel with the last direction of ice-flow as ascertained, not by striae, which may belong to any stage, but by the convincing and unequivocal evidence of the moraines and the marginal drainage. Not wishing to labour the point further, the sceptical reader is merely referred to the map and description on Kinahan and Close's account of the glaciation of Iar Connaught, to H. L. Fairchild's map of the drumlins of western central New York,[1] and to my own maps of north-west Ireland [2] and south-west Scotland.[3] That the drumlins of the Glasgow area and of Renfrew, according to Professor Gregory, are not coincident with the lines of ice-flow as worked out from striae and the distribution of erratics, is due I think to the fact that his drumlins in many cases are not true drumlins, as I have long suspected from examining them in passing through the district, though I make no pretence of having studied them attentively, and also to the uncertainty as to the last direction of ice-flow, which is the determining factor in the control of drumlin trends. When this has been definitely ascertained, there will most assuredly be less discrepancy between these directions than Professor Gregory would lead us at present to believe.

It is a most striking feature, to which I hope to draw attention in the near future, that drumlins, wherever they abound, approximate to a definite size. While it would seem intelligible that such should be the case were these features moulded by a moving ice-sheet, being related to its plasticity, its thickness and its velocity, such an approximation on Professor Gregory's view would appear both meaningless and inexplicable.

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[1] *New York State Mus. Bull.*, 111 (1907).

[2] *Proc. Roy. Irish Acad.*, xxxvi, sect. B (1924), p. 174.

[3] *Trans. Roy. Soc. Edinb.*, lv (1926), p. 1.

Drumlins in longitudinal profile are usually asymmetrical; the one end is broader, blunter, higher, and steeper, the other, narrower and more tapering. The blunter end is almost always, if not invariably, the stoss end of the drumlin. This was early pointed out by Maxwell Close, in 1866,[1] was re-affirmed by the same writer, and by G. H. Kinahan, in their conjoint paper on the General Glaciation of Iar Connaught,[2] and was also found to be true for Donegal by Harte and myself.[3] This relation was subsequently confirmed for the drumlins of North America by F. Wahnschaffe,[4] from observations in Wisconsin, by L. Johnson,[5] for the drumlins of west New York, by R. S. Tarr,[6] and W. C. Alden,[7] and by H. L. Fairchild,[8] for the drifts of western central New York. On the continent of Europe the same law appears to hold good, as has been maintained for Pomerania by K. Keilhack,[9] for parts of Switzerland by H. W. B. Hellmund,[10] and J. Früh,[11] and by A. Baltzer for the Arnex district [12] of that country and also for Rügen.[13] I have found the same in connexion with the drumlins of Galloway, Carrick, and Kintyre in Scotland, of Down, Armagh, and Kerry in Ireland.

The only statements, so far as my reading goes, which are exceptional to this rule are the general one by H. C. Lewis,[14] subsequently contradicted by later workers on the same drumlins, and the more particular one made recently for the Carlisle area.[15] In this case, though I am extremely reluctant to hazard an opinion about an area which I have not personally examined, it would seem, judging from the general rule just expressed, probably because of the complexity of the glacial history in that area that a false determination of the direction of ice-flow, responsible for the drumlin formation, has been made.

The general rule that drumlins present their steeper and blunter ends to the ice, no matter whether the ground be sloping away from or toward the ice, is sustained by simple physical laws. The drumlins have accommodated themselves in such a way that they offer the least resistance to the flow of the ice above and around them, and the greatest resistance to their own removal. This is in accordance with the form of sand and gravel bars in rivers, with snow forms, as those observed and described from the Antarctic,[1] with the stream lines of flow in plastic media, as beautifully illustrated in Dr. Hele Shaw's paper,[2] and with the practical applications of this principle as seen in the shape of fishes, torpedoes, and racing cars.

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[1] *Journ. Roy. Geol. Soc. Ireland*, i (1866), p. 231.

[2] 1872, p. 7.

[3] Op. cit., p. 200.

[4] *Zeit. deutsch geol. Gesell.*, xliv (1892), p. 116.

[5] *Trans. New York Acad. Sci.*, i (1882), p. 77.

[6] *Bull. Amer. Geol. Soc.*, xxx (1898), p. 219.

[7] U.S.G.S. Prof. Paper 106 (1918), p. 254.

[8] Op. cit., p. 405.

[9] *Jahrb. preuss. geol. Landesanstalt* for 1896 (1897), p. 179.

[10] *Viertel jahresschrift d. Naturf. Ver. Zurich* (1909), p. 165.

[11] *Jahresber. d. naturw. Ver, St. Gallen*, 1896.

[12] *Ecl. Geol. Helv.*, vi (1900), p. 378.

[13] *Zeit. deutsch. geol. Gesell.*, li (1899), p. 563.

[14] *Glacial Geology*, etc. (1894), pp. 116–17.

[15] *Mem. Geol. Surv. Carlisle, Longtown, and Silloth District* (1926), p. 53.

On the orthodox theory this form of drumlin is readily understandable. But how explain the asymmetry by wind and rain ?

The distribution of drumlins is another difficult hurdle for the post-glacial theory. Why should the boulder-clays of certain regions only be sculptured into these forms ? There are great boulder-clay plains in the peripheral parts of all glaciated regions even in the areas of the newer drifts, which are completely destitute of drumlins, and, still more puzzling, other areas totally surrounded by drumlin tracts where these features are also entirely absent. Again, how elucidate the apparently capricious rise of a perfect drumlin out of an otherwise completely flat plain of boulder-clay. On the glacial theory, involving as it does many unknown factors, e.g. plasticity, thickness, and velocity of the ice, etc., the explanation is admittedly difficult enough, and the final and convincing solution not yet available. The simple explanation of Professor Gregory, however, can surely offer no helpful answer. Furthermore, why are drumlins not developed in the Mesozoic clay lands of England and elsewhere where wind and rain are not unknown ? To say that drumlin-like forms occur in the London Clay areas south of the glacial margin is to tax credulity unduly.

One of the most serious difficulties, however, encountered by Professor Gregory's theory still remains to be considered, namely, the question of the time of drumlin formation. Upon this point we are fortunately well informed. As has been emphasized again and again where drumlin and moraines are associated together, the drumlins lie invariably beneath the recessional accumulations. Likewise eskers, or osars as Professor Gregory would prefer to call them, are found not only resting upon or running over the drumlins but are even seen to side step in zig-zag course across them. Important from the point of view of the time of these formations is also the well-attested fact that they underlie late-glacial clays, as the Yoldia Clays of Scandinavia [3] and the Champlain Clays of North America,[4] and that they are scarped by the waters of the late-glacial lakes, e.g. Lakes Warren and Iroquois [5] (with the formation of bars and spits) and by the waters of similar lakes in Europe, as in the Carlisle area,[6] where the strand-lines of " Lake Carlisle " cut across the sides and summits of the drumlins. The scarping of the drumlins by the 25, 50 and 100 foot seas of Scotland constitutes still further proof if more were needed, as is well shown in Kintyre and Galloway and also in the north of Ireland (25 foot).

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[1] C. S. Wright, *British* (*Terra Nova*) *Ant. Exped.*, 1910–13, *Glaciology* (1922), p. 34.

[2] *Trans. Inst. Mech. Engineers.* I am indebted to my colleague, Professor Hummel, for kindly referring me to this paper.

[3] E.g., A. G. Hogbom in Steinmann's *Handbuch der Regional Geologie*, iv (1913), p. 97.

[4] E.g. B. K. Emerson, *U.S.G.S. Mon.*, xxiv (1898), p. 702.

[5] H. L. Fairchild, op. cit., pp. 396, 408.

[6] Op. cit., p. 57.

The hollows between the drumlins which manifestly on any theory cannot antedate the mounds which enclose and form them also witness to an early date; the occasional discovery in lake-marls, on such sites, of the remains of Irish Elk, which died out in early post-glacial times, constitutes incontrovertible proof of this early period of drumlin formation.

The post-glacial denudation theory is also quite unable to account for such features as the coincidence in direction of the drumlins and their larger striated boulders,[1] the concentric bedding, parallel with the drumlin surface, which has sometimes been clearly observed,[2] and is usually attributed to the plastering on of successive layers in the building up of the mounds. Nor again can that theory account for the occurrence of rock drumlins practically indistinguishable in shape from the typical boulder-clay mound,[3] nor for the gradual transition as we proceed to the lee from a rock-drumlin [4] (which can only be an ice-moulded form) into a typical drumlin of boulder-clay, as shown for example from south of Thur [5] by J. Früh, and by myself from Donegal. Equally obscure on that theory is the closely related observation of the frequent transition from *roches moutonnées* with " tails " into drumlins with the core completely covered over,[6] and the occasional discovery of drumlins, the stoss half of which is rounded rock, the lee half boulder-clay.

Though there still remains some powder in the locker, I think sufficient evidence has been brought together to show that the glacial theory (ignoring its variant forms), for many years now regarded almost as axiomatic, offers a far more satisfactory explanation than that which would ascribe the drumlins to post-glacial subaërial erosion by wind and rain as recently re-advocated by Professor Gregory.

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[1] E.g. A. G. Hogbom, *Bull. Geol. Inst. Upsala*, vi (1903), p. 180.

[2] E.g. B. K. Emerson, op. cit., p. 540; H. L. Fairchild, op. cit., p. 416.

[3] R. D. Salisbury, *Geol. Surv. New Jersey*, v (1902), p. 543.

[4] H. L. Fairchild, op. cit., p. 393.

[5] *Ecl. Geol. helv.*, viii (1904), p. 213.

[6] A. G. Hogbom, *Bull. Geol. Inst. Upsala*, vi (1903), p. 183.

The Hereford Earthquake of 15th August, 1926.

By Charles Davison, Sc.D., F.G.S.

THIS important earthquake is chiefly of interest on account of its connexion with the strong Hereford earthquakes of 6th October, 1863, 30th October, 1868, and 17th December, 1896. At least three of the four earthquakes (those of 1863, 1896, and 1926) seem to have originated in the same twin-foci, the epicentre of one lying near Hereford and that of the other near Ross. The fourth earthquake (that of 1868) originated in the Ross focus, possibly also in the Hereford focus.

The recent series consists of two fore-shocks and the principal earthquake. In addition to these, there may have been a fore-shock on 14th August, at about 9 p.m., at Easton Court (near Tenbury), and an after-shock on 5th September, at 12.41 p.m. at Woodcote (near Newport in Shropshire). But, as both depend on single observations, their seismic origin should, I think, be regarded as not established.

Fore-shocks.—15th August, 3 a.m., a slight shock felt at Weobley Marsh (near Leominster) and Little Hereford (near Tenbury). A rumbling sound was also heard at Llandrindod Wells.

15th August, about 4.50 a.m., a slight tremor felt at Ross and Wormelow (south of Hereford), and, at the latter place, accompanied by a loud rumbling noise.

Principal Earthquake, 15th August, 4.58 a.m.—Intensity 7: centre of isoseismal 6 in lat. 51° 59·0′ N., long. 2° 40·0′ W.; number of records 1,361, from 850 places.[1]

Owing to its occurrence at a time when many persons were lying awake and at rest, the principal shock was felt over an unusually wide area. It was observed in all but the four northern counties of England, and in every Welsh county, that is, altogether in forty-four counties.

Isoseismal Lines and Disturbed Area.—On the map of the earthquake, three isoseismal lines are drawn, corresponding to intensities 6, 5, and 4 of the Rossi-Forel scale. The isoseismal 6 is 66 miles long from north-west to south-east and 50 miles wide, and contains 2,600 square miles. Its centre lies about six miles south-east of Hereford. The isoseismal 5, which depends on a very large number of observations, is 226 miles long, 210 miles wide, and 37,600 square miles in area. Except towards the north and east, the course of the isoseismal 4 is somewhat doubtful. As drawn, it is 353 miles long, 323 miles wide, and it contains about 90,000 square miles. This curve is the boundary of the disturbed area.

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[1] I am indebted to the editors of a large number of newspapers for their courtesy in printing my letters of inquiry and to more than 1,200 correspondents for their kindness in answering them; also to Professor H. H. Turner, F.R.S., and the Directors of the Meteorological Office and the Kew Observatory for allowing me to read letters written to them.

The most remarkable feature of the isoseismal lines is their great ize, especially those of intensities 5 and 4. It is, no doubt, due o the observations being made, almost without exception, on the pper floors of houses. The areas given are thus not quite comarable with those determined for other earthquakes.[1] In any

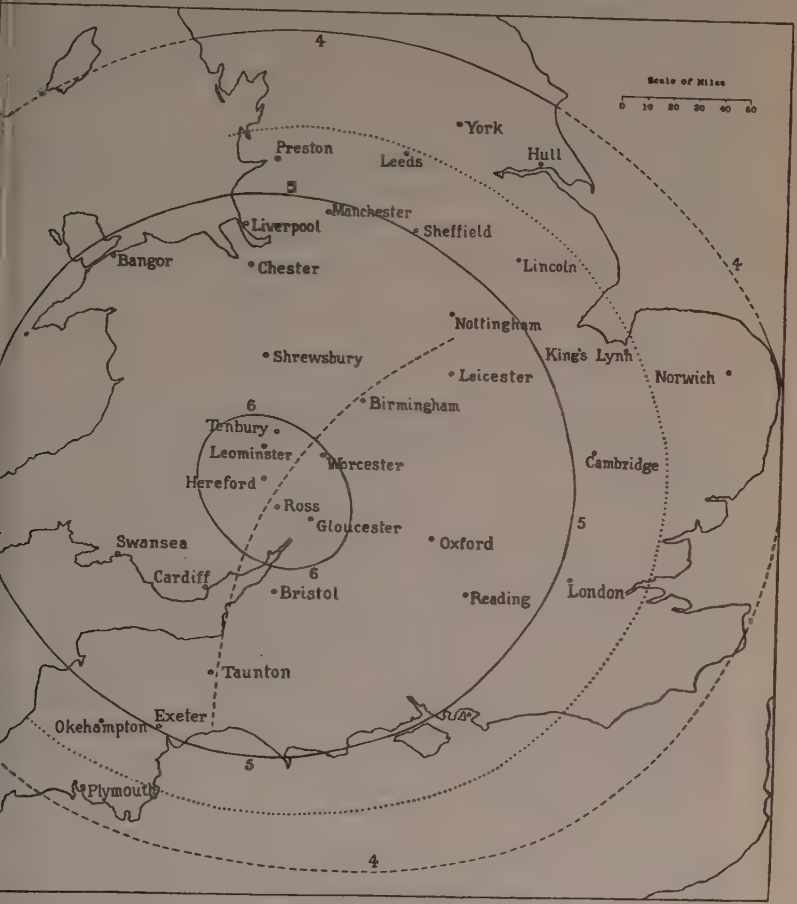

Fig. 1.—Map of the earthquake area, 15th August, 1926.

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[1] In the Stafford earthquake of 14th January, 1916, I was able to draw two ries of isoseismal lines of intensities 5, 4, and 3, depending on observations ade respectively on the ground-floor and on upper-floors. The two isoseismals re practically identical. The areas of the isoseismals 4 and 3 are 6,570, and out 16,500 square miles for ground-floor observations, and 12,500 and 50,200 uare miles for upper-floor observations (*Amer. Seis. Soc. Bull.*, vol. ii, 1921, . 122–4).

case, however, they seem to point to a depth of origin greater than the average.

From the form and position of the isoseismals 6 and 5, it follows that the direction of the earthquake-fault is approximately north-west and south-east. The curves are too far apart (85 miles towards the north-east and 76 miles towards the south-west) to determine the hade of the fault with accuracy, but it is possible that the fault hades to the north-east. If so, the fault-plane, if produced, would intersect the surface along a line passing close to Hereford. The elements of the fault thus, so far, agree with those determined by the earthquake in 1896.

Of the four Hereford earthquakes, the recent shock occupies the third place as regards intensity, as will be seen from the following table :—

Date.	*Intensity.*	*Disturbed Area in sq. miles, about.*
1896	8	98,000
1863	8	85,000
1926	7	90,000
1868	7	10,000

Nature of the Shock.—Throughout a large part of the disturbed area, the shock was observed to consist of two distinct parts. For instance, at

King's Lynn, two parts were felt, the first and stronger, a rocking motion, lasted several seconds, followed, after an interval of about a second, by the other, a mere tremor and lasting about two seconds ; or, in the words of an observer near Bedford, the second and weaker part immediately followed the other like an echo.

Okehampton (Devon), there were two distinct shocks, the second stronger, with an interval of a few seconds between them.

In the south-eastern half of the disturbed area, the first part was much the stronger ; in the north-western half, the second. Moreover, the two portions are separated by a hyperbolic curve (indicated by the broken line on the map). This curve crosses the isoseismal 6 almost at right angles to its axis, passing between the Hereford and Ross epicentres, and it coincides very nearly with the corresponding curve of the earthquake of 1896. Along this curve, which I have called the *synkinetic line*, and within a short distance on either side, the two parts of the shock coalesced. For example at Birmingham, according to two observers, the shock consisted of two parts, the first stronger and of longer duration, but the movement did not quite die away in the interval.

The average duration of the interval between the two parts of the shock was 2·8 seconds throughout the whole disturbed area. Allowing for the extinction with increasing distance of the terminal tremors of the two parts, the average duration of the interval was nearly constant at varying distances from the origin. It was

2·2 seconds within the isoseismal 6, 2·9 seconds between the isoseismals 6 and 5, and 3·0 seconds between the isoseismals 5 and 4.

Taking into account the form and position of the isoseismal 6, the position of its centre, and the course of the synkinetic line, it may, I think be concluded: (i) that the earthquakes of 1926 and 1896 originated in the same deeply-seated foci situated nearly below Hereford and Ross; (ii) that the Hereford focus was in action shortly (perhaps about two seconds) before the other, since the vibrations from the Hereford focus travelled farther than those from the Ross focus before the two series coalesced along the synkinetic band; (iii) that the interval between the two impulses was so short that the Ross focus came into action before the waves from the Hereford focus had time to reach it; otherwise, there would have been no synkinetic band; (iv) that this interval was almost of exactly the same duration in both earthquakes; and (v) that the impulse in the Ross focus in 1926 was much stronger than that in the other.

That the impulse within the Hereford focus was, nevertheless, of considerable strength is shown by the extent of the area over which the twin-shock was observed. This area overlaps the isoseismal 5 by from 5 to 10 miles (and at King's Lynn by 29 miles) towards the east and south-east, and by 6 miles towards the south-west.[1] It is thus about 240 miles long from north-west to south-east, about 220 miles wide, and its area is about 41,500 square miles.

Sound-Phenomena.—The boundary of the sound-area is indicated by the dotted line on the map. Roughly, it lies about midway between the isoseismals 5 and 4. Its length is about 320 miles, its width about 270 miles, and its area about 74,000 square miles, or four-fifths of that of the disturbed area.

Throughout the whole sound-area, the sound was heard by 56 per cent. of the observers. Even within the isoseismal 6, the percentage was no higher than 82. In the zone between the isoseismals 6 and 5, it was 57, and, in the zone between the isoseismal 5 and the boundary of the sound-area, 32.[2] These low figures and the great size of the sound-area seem to point to a focus of unusual depth.

On another map I have drawn a series of isacoustic lines or lines passing through the centres of areas in each of which the percentage of audibility was the same. They are not reproduced on the accompanying map, as, in several counties, the number of

[1] The twin-shock would naturally be felt farther towards the south-east than in the opposite direction, as the attention of observers there would be roused by the stronger initial movement.

[2] In strong British earthquakes (that is, with disturbed areas of more than 5,000 square miles) the average percentage of audibility is 97 within the central isoseismal, and 94, 87, 68, and 55 within the zones bounded by successive isoseismals.

observations was too small to enable me to feel confidence in their accuracy. As in the earthquake of 1896, however, they are distorted along the course of the synkinetic band. This is clearly shown by the percentages of audibility in the counties with numerous observations. For instance, along the synkinetic band the percentage was 86 in Herefordshire, 83 in Somerset, 65 in Worcestershire, 63 in Warwickshire, about 69 in Leicestershire, 74 in Nottinghamshire, and 57 in Lincolnshire. At a distance from the synkinetic band, the percentage was 57 in Buckinghamshire, and 62 in Northamptonshire, but 37 in Cheshire, 35 in Lancashire, 33 in Hampshire, 40 in Oxfordhire, 33 in Surrey, and 19 in Middlesex. The greater audibility of the sound within and near the synkinetic band is no doubt due to the coalescence of the sound-vibrations from the two foci.

In its nature, the earthquake-sound closely resembled other British earthquakes of the same intensity. It was compared to passing vehicles (usually motor-lorries) in 45 per cent. of the records, thunder in 22 per cent., wind in 13, loads of stones falling in 5, the fall of a heavy body in 2, explosions in 9, and miscellaneous sounds in 4, per cent. The average figures for strong British earthquakes are, respectively, 45, 20, 11, 4, 7, 8, and 5. As the sound-waves diverged from the epicentres, there was very little change in the nature of the sound.

Origin of the Earthquakes.—Of the three undoubted earthquakes, the earliest probably occurred in the Hereford focus, and the second, less than two hours later, in the Ross focus. Ten minutes afterwards came the great movements almost simultaneously in both foci, slightly earlier in the Hereford focus, but with distinctly greater violence in the Ross focus. There is no certain evidence of any subsequent movement, either in one of the foci or, as is so often the case, in the interfocal region.

The earthquakes of the Hereford district are connected with two faults. The more important and deeply seated fault,[1] with which the strong earthquakes of 1863, 1868, 1896, and 1926 were connected is directed N. 46° W., its hade is to the north-east, and it passes close to Hereford. The other, a comparatively superficial fault, passes through, or nearly through, the Hereford epicentre, in the direction N. 65° E., or roughly at right angles to the principal fault.

All four principal earthquakes, with the possible exception of that of 1868, were twins and originated in the same foci. In 1863, 1896, and 1926 the Hereford focus was first in action. In 1863, 1868, and 1926 the stronger impulse occurred in the Ross focus; in 1896, in the Hereford focus. The simple and much slighter earthquakes of 27th March, 1853, and 26th January, 1924, were, I imagine, due to an increase of stress along the superficial fault brought about by movements in the deeply seated fault.[1]

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[1] That the fault is situated at a great depth is clearly shown by the magnitudes of the disturbed areas of two fore-shocks of the earthquake of 1896. Both were probably of intensity 4, yet their disturbed areas contained as much as 6,300 and 6,400 square miles. The average disturbed area of British earthquakes of the same intensity is 400 square miles.

Thus, all the known Hereford earthquakes were due to crust-movements along one system of folds—the twin-earthquakes and their minor shocks to the growth of the deep-seated north-east–south-west fold along a fault cutting it transversely, the simple earthquakes to slips along a superficial fault nearly parallel to the same direction.

The Petrology of the Avonian Rocks at Sodbury, Gloucestershire.[2]

By A. W. Coysh.

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I. Introduction.

THE Carboniferous Limestone section in the railway cutting at Sodbury was described by the late Dr. A. Vaughan in his paper on the Bristol Area,[3] and Professor S. H. Reynolds has studied the lithology in detail.[4]

The present paper deals with the insoluble residues of the limestones, and the mineralogical contents of the arenaceous beds associated with them, with a view to investigating the conditions of deposition.

Many of the residues were prepared from the actual specimens from which the thin sections were cut for Professor Reynolds' paper, supplemented by material collected personally from the cutting and neighbouring quarries.

In the following accounts, the calcareous and arenaceous rocks are considered separately.

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[1] *History of British Earthquakes*, 1924, pp. 244–59.

[2] An abstract of this paper was read before Section C of the British Association, Oxford, 1926.

[3] *Q.J.G.S.*, vol. lxi, 1905, pp. 204–11, and vertical section, plate xxvii.

[4] Geol. Mag., Vol. LX, 1923, pp. 111–19. This will be referred to as the "Lithology Paper"

II. Notes on Petrological Methods.

The method of treating the limestones has been essentially the same as that employed by Mr. E. Wethered in his work on the rocks of the Avon section,[1] except that they were broken up into small fragments before solution.

A quantitative estimation of the insoluble residues was first carried out, after which they were examined microscopically, the diameters of the detrital quartz grains being measured.

The examination of the non-calcareous rocks in the laboratory, which was carried out in the usual way, was preceded by careful study in the field, in which their special characters, such as bedding and ripple marking, were carefully noted.

A more detailed measurement of these horizons has been given in a later section of this communication than was recorded in the " Lithology Paper ".

III. Insoluble Residues from the Limestones.

(a) *Quantitative Results.*

The results tabulated below are arranged in stratigraphical order beginning with the lowest beds (Km)[2]:—

No.	Horizon.	Bed.	Lithology.	% Insol. Residue.	Size of Quartz grains in mm.
S 86	Km	1	Compact sandy limestone	27·4	0·02–0·06 and 0·1–0·2
S 85	Km	1	" " "	41·6	0·08
S 84	Km	1	" " "	14·0	0·05
S 81	Km	1	" " "	32·9	0·06
S 80	Km	1	" " "	24·4	0·06
S 79	Km	1	" " "	49·2	0·06
S 78	Kα	2	Bryozoa Bed	13·6	0·07–0·09 and 0·2–0·4.
S 76	K_1	3	Coarse rubbly limestone	2·4	0·1
S 75	K_1	3	Sandy limestone	?	0·1
S 74	K_1	3	Sandy crinoidal limestone	?	0·08 and few 0·5.
S 172	K_1	3	Argillaceous dolomite	3·9	0·08
S 170	K_2	4	Dolomitized crinoidal lst.	6·6	0·07
S 73	K_2	4	Sandy limestone	34·5	0·05
S 72	K_2	4	Crinoidal limestone	6·0	0·08
S 71	Z_1	5	" "	3·2	0·07
S 70	Z_1	5	Dolomitized limestone	0·6	0·01
S 168	Z_1	5	" "	0·6	0·03
S 167	Z_1	5	Coarse crinoidal limestone	0·7	0·05

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[1] *Q.J.G.S.*, vol. xliv, 1888, p. 189.

[2] As there is no definite distinction between a sandy limestone and a calcareous sandstone, all rocks with more than 50 per cent. of insoluble residue are treated in the arenaceous and argillaceous division of this paper.

The number in the first column refers to the corresponding thin section in the University of Bristol collection, that in the third column being the number assigned to the bed in the " Lithology Paper ".

No.	Horizon.	Bed.	Lithology.	% Insol. Residue	Size of Quartz grains in mm.
S 165	Z_1	6	Brecciated dolomite	0·5	—
S 164	Z_1	6	Dolomitized crinoidal lst.	0·5	—
S 163	Z_1	6	,, ,,	7·3	0·05
S 162	Z_2	7	,, ,,	3·1	0·04
S 158	Z_2	7	,, ,,	4·1	0·03
S 65	Z_2	7	Fine-grained dolomite	7·1	0′05
S 63	Z_2	7	Fine crinoidal limestone	2·5	0·05
S 152	$C_1(a)$	8	Coarse grained dolomite	3·6	—
S 151	$C_1(a)$	8	Compact dolomite	3·4	0·05
S 60	$C_1(a)$	10	,, ,,	0·3	0·02
S 143	$C_1(b)$	11	Oolitic limestone	0·3	—
S 54	$C_1(b)$	11	Fine oolitic limestone	2·9	0·03
S 53	C_2	12	Compact limestone	5·0	0·03
S 136	C_2	17	Compact dolomite	9·4	Up to 0·01
S 47	C_2	17	Fine dolomite	14·3	0·02–0·04
S 46	S_1	19	Argillaceous limestone	11·5	—
S 132	S_1	19	Calcite mudstone	2·5	0·04
S 44	S_1	20	Sandy limestone	36·6	0·07–0·30
S 32	S_1	23	*Seminula* pisolite	3·2	0·04
S 29	S_1	23	Dolomitized limestone	3·5	0·04
S 129	$S_2(a)$	25	Sandy limestone	23·2	0′08
S 128	$S_2(a)$	25	Dolomite	0·2	0·06
S 127	$S_2(a)$	25	Limestone	8·9	0·04
S 27	$S_2(b)$	26	Coarse oolite	0·9	0·06
S 24	$S_2(b)$	26	Oolite	0·7	0·04
S 123	$S_2(b)$	27	Limestone	0·9	0·07
S 118	$S_2(c)$	29	Foraminiferal limestone	1·5	0·06
S 114	$S_2(c)$	29	Limestone	5·7	0·08
S 18	$S_2(c)$	29	Foraminiferal limestone	2·1	0·06
S 113	$S_2(d)$	30	Concretionary limestone	5·5	0·03
S 102	$S_2(d)$	30	Oolite with quartz	2·6	0·08
S 10	$S_2(d)$	32	Fine oolite	2·0	0·08
S 96	$S_2(d)$	33	Compact limestone	6·4	0·05
S 13	$S_2(d)$	33	Algal limestone	5·4	0·04
S 5	D_1	35	Oolitic limestone	0·0	—
S 95	D_1	35	,, ,,	0·0	—
S 93	D_1	36	Limestone	7·1	0·04
S 92	D_1	36	Foraminiferal limestone	4·5	0·03 to 0·3
S 89	D_1	37	,, ,,	0·0	—
S 1	D_1	37	,, ,,	0·0	—

(b) *The Mineralogical Constitution of the Residues.*

The *Cleistopora* Beds.—Detrital quartz is common in all the residues, the amount being rather greater than in the Z and C beds. Other forms of silica are often present, and in the limestone immediately above the Bryozoa Bed siliceous pseudomorphs after crinoid ossicles and polyzoans were found.

Among the rarer constituents, magnetite, pyrites, zircon, ilmenite, tourmaline, muscovite, and a little plagioclase felspar have been recorded. Very little argillaceous matter is present.

The *Zaphrentis* Beds.—The residues on the whole are similar to those of the *Cleistopora* beds, but contain less detrital quartz and more argillaceous matter. Siliceous pseudomorphs after crinoid ossicles occur in a dolomitized crinoidal limestone in Z_1, and sponge spicules are common throughout this sub-zone. Pyrites, zircon, tourmaline, and muscovite are present.

The *Syringothyris* Beds.—The percentage of insoluble residue increases throughout C_2. Detrital quartz is fairly abundant and other forms of silica occur. Pyrites is very abundant and muscovite and fluor have been recorded, the latter from a fine-banded chinastone in C_2.

The *Seminula* Beds.—The percentage residues are larger in S_1, than in S_2. They contain more argillaceous matter than most of the limestones in the sequence. Detrital quartz is common and a few sponge spicules occur in a limestone in S_2. Pyrites is very abundant as an authigenous constituent and this may be attributed to derivation from the overlying Rhaetic bone bed, the mineral being absent from the D beds, which are directly overlain by Trias. In a calcite mudstone in S_1, cubes with an average diameter of 0·9 mm. occur. Magnetite is common at certain levels.

The *Dibunophyllum* Beds.—Residues examined from these beds contained quartz and a little magnetite but no pyrites. The majority of the limestones contain little or no insoluble residue, being mainly very pure white current-bedded oolites. The rocks of the *Dibunophyllum* zone in the Bristol area are as a rule very deeply iron-stained.[1]

This seems to be due to the position of the ferruginous Triassic marls and conglomerates. The D beds usually form the flanks of anticlinal uplifts on the sides of which the Triassic deposits have been laid down. This is certainly the case at Wrington and to a certain extent in the Avon gorge.

In the Sodbury section [2] and in the town quarries the limestones are separated from the Keuper marls by a buff-coloured dolomitic limestone, often sandy and containing less than 4 per cent. of iron oxides.[3] This may partially explain the non-ferruginous character of the D beds in this area.

The oolitic character of the limestones and their freedom from terrigenous matter suggests rapid accumulation in warm shallow waters saturated with calcium carbonate and lying off land of low relief supplying little sediment.

Notes on the constituents of the residues.—In practically all the residues silica is the most abundant constituent. It occurs as quartz grains, amorphous, cryptocrystalline and microcrystalline silica, sponge spicules and pseudomorphs after organic remains.

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[1] S. H. Reynolds, *Geological Excursion Handbook for the Bristol District*, 2nd ed., 1921, pp. 42, 72, and 177.

[2] Reynolds, ibid., horizontal section, p. 197.

[3] Analysis by Dr. Pollard, *Mem. Geol. Surv., Summary of Progress for 1898*, p. 192.

Quartz occurs as detrital grains varying in size; in K they are relatively large, the average size in the more pure limestones being 0·07 mm., and in the more sandy beds from 0·1 to 0·4 mm. Throughout Z and C the size is fairly constant, ranging as a rule between 0·03 and 0·05 mm. In S and D the average size is greater, being about 0·06 mm., though near the arenaceous bands they may be 0·3 mm. in diameter. Where grains of two sizes occur, the larger ones are more or less angular. On the whole, however, the detrital quartz is distinctly subangular.

The grains are sometimes clear, but in the main show rows of minute inclusions. Needle-like inclusions of zircon occur in many of the crystals, while some have curious black spots, the origin of which is obscure. In a few cases undulose extinction has been noted, suggesting derivation from metamorphic rocks. The grains of quartz are often seen in thin sections of the limestones and may form nuclei to the ooliths in oolitic rocks. In a calcite mudstone in S_1 small angular quartz grains form lenticular layers, as though laid down by gentle currents.

Amorphous silica is very common in many of the residues, occurring as clear margins to irregular dark fragments. It is isotropic and has a low R.I. compared with Canada Balsam. Grains of quartz are sometimes enclosed in the amorphous silica.

Cryptocrystalline silica occasionally occurs in grains with finely speckled surfaces. They are birefringent in very minute detached spots.

Microcrystalline silica is very similar to the cryptocrystalline variety, but extinguishes in larger spots.

There is no evidence of the origin of the silica in the limestones other than the detrital quartz. In its original state it was probably deposited as a chemical precipitate of gelatinous silica and has now become amorphous, cryptocrystalline or microcrystalline. Siliceous pseudomorphs after organic remains are found in crinoidal limestones in K and Z, where silica replaces the calcium carbonate of crinoids and polyzoans.

Sponge spicules are fairly abundant in Z_1, and rarer in K and S_2(b). They seem to have been replaced by crystalline silica, the axial canal being filled with the same material. They occur as fragments with a diameter ranging from 0·03 to 0·1 mm. No nodes have been seen, and they are therefore indeterminable.

Fluor was isolated from a fine-grained limestone in C_2 by crushing the rock and carrying out a bromoform separation. It occurs as small colourless grains, which are apparently detrital. This mineral has been recorded from S_2 in the Mendips and from the Avon section, where it is original.[1]

Magnetite is common in a few of the limestones, occurring as irregular grains.

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[1] Reynolds and Vaughan, *Q.J.G.S.*, vol. lxvii, 1911, p. 347.

Pyrites is very abundant in most of the residues. It usually occurs as small aggregates of crystals, often coating and cementing together other mineral grains. For this reason it has proved very troublesome in the examination of the slides. In one rock it occurred as large cubes (0·9 mm.) with the (111) face slightly developed. It may sometimes be seen covering the surface of a joint plane with minute crystals and megascopic crystals occur in a few of the limestones. Its deposition from infiltrating waters on the joint planes supports the idea that it has been derived from the Rhaetic rocks. The mineral was noted in the residues of the Clifton rocks and has also been recorded from limestones in North Wales.[1] It is possible that the so-called "bituminous" smell and black colour of many limestones when freshly fractured may be due in many cases to the presence of pyrites.

Zircon is fairly common in the limestones of the *Cleistopora* zone, but is rarer in higher beds. It is usually colourless, though sometimes pink. It may occur in the form of rounded grains, of short stout prisms (0·02 mm.) or of more slender and needle-like prisms terminated by pyramids (0·06 mm.) They often contain inclusions. Ilmenite occurs rarely as rounded grains coated with leucoxene. Tourmaline is rare, but small prismatic grains have been seen. They are of a grey colour, very pleochroic.

Muscovite occurs fairly frequently as irregular flakes. Biotite is rare, only one or two flakes having been noticed. Felspar is also rare. Plagioclase felspar has been found in the K beds.

IV. ARENACEOUS AND ARGILLACEOUS ROCKS.

Sandstones,[2] siltstones, and shales occur at several horizons as indicated by Professor Reynolds (op. cit., pp. 118–19) and are more important than in the Avon section. They have been studied in considerable detail, and fuller accounts are therefore given here than in the "Lithology Paper".

The *Cleistopora* Beds.—Sandstones and shales are of frequent occurrence in Km and K_1, becoming less important in K_2. The sandstones are mainly calcareous, the quartz grains (up to 0·2 mm.), which are usually angular, being cemented together by calcite or limonite.

The rarer constituents include magnetite, ilmenite, zircon, tourmaline, muscovite, biotite, and felspar.

The *Zaphrentis* and *Syringothyris* Beds.—No sandstones occur in these beds, though a little shale occurs in C_2.

The *Seminula* Beds.—This zone contains the main development of sandstone and shale within the sequence.

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[1] T. A. Jones, *Proc. Liverpool Geol. Soc.*, vol. xiii, part ii, 1921, pp. 78–99.

[2] In this paper the term "grit" has been suppressed owing to its indefiniteness. The rocks have been termed sandstones and siltstones according to the grade of their mineral particles.

In S_1 there is a massive sandstone band 13 feet thick (i.e. bed 22 of the "Lithology Paper"). The quartz grains are packed closely together, there being practically no cement.

Shale and thin bands of calcareous sandstone occur at various levels in the succeeding S_1 beds.

In the lower part of S_2 (*d*) there is a band of current-bedded sandstone 4 feet thick, overlain by 3 feet of shale. At a slightly higher horizon (bed 31) the following beds occur:—

Sandstone, slightly micaceous	1 foot.
Shale	1 "
Sandstone	1 "
Shale, calcareous	3½ "

The most important section of arenaceous and argillaceous rocks is at the top of S_2 (*d*)—the Third *Modiola* Phase (bed 34).

The following are the bands in ascending order:—

	ft.	in.
Shale, carbonaceous	3	6
Sandstone, micaceous and showing worm tracks and ripple marks[1] (index 5)	3	0
Sandstone, soft, red, and calcareous with many pebbles of vein quartz (up to 2 cm. diam.), grading up into sandy shale becoming black towards the top	13	0
Sandstone with irregular surface showing ? desiccation cracks	1	0
Shale, red and dark grey	3	0
Sandstone with shale partings. The lower part is a red micaceous siltstone with ripple marks (index 6·6).	3	6
Shale, light green at base, red towards the top	1	6
Sandstone, irregular, average thickness		6
Shale, dark grey	4	6
Sandstone, micaceous, with one shale parting. Symmetrical ripple marks (index varies 7 to 12)	3	8
Shale, black and micaceous	2	6
Sandstone, very compact, with thin shale partings	2	0
Shale, sandy and micaceous	2	6
Total thickness	44	2

The following minerals have been found by a petrographic examination of these beds. Zircon, ilmenite, tourmaline, magnetite, muscovite, rutile, and staurolite (in order of abundance).

The *Dibunophyllum* Beds.—Definite bands of sandstone are absent but masses of "pebbly grit" occur in the limestone about 30 feet from the base of the zone. These have been fully described and discussed in the "Lithology Paper". The possibility suggested that these masses may be infillings is rendered exceedingly doubtful by the fact that the mineral assemblage is identical with that of the other arenaceous beds of the sequence. Another factor which negatives this idea is the widespread occurrence of these sandy patches, for Miss M. C. Tuck has recently described an exposure of the same band over half a mile north of the cutting.[1]

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[1] See E. M. Kindle, *Geol. Surv. Canada Mus. Bull.* 25 (1917), p. 12. He defines a ripple mark index as the "ratio of the depth and width of troughs."

The other hypothesis put forward by Professor Reynolds seems more probable—that they are in part the result of local deposition of excess of sandy material and are in part due to subsequent segregation.

Characters of the chief detrital minerals in the arenaceous beds.—Quartz is the main constituent of the rocks, being present in grains which are chiefly subangular (up to 0·6 mm. diameter). They often show rows of minute inclusions which are sometimes pulled out into parallel bands due to strain. Needle-like inclusions of zircon are also fairly common.

Magnetite is plentiful in well-rounded grains (0·3 mm.). Rutile is always well rounded, occurring as foxy red grains with an average diameter of 0·2 mm.

Zircon is very common, mainly as small ovoid and fractured grains (0·1 mm.), though occasionally prismatic grains capped by pyramids are seen. A noteworthy feature is the presence of many grains with a distinct pink colour. Some grains show regular inclusions arranged perpendicular to the length of the crystal. Ilmenite is exceedingly abundant, occurring as irregular rounded grains (0·2 mm.).

Tourmaline occurs as the brown and dark grey varieties, the latter showing intense pleochroism. The grains are usually well rounded or irregularly fractured (0·15 mm.), prismatic crystals being rare. Muscovite occurs in small flakes. It may often be seen in the crushed material, before separation or mounting.

Staurolite (0·15 mm.) occurs as yellow irregular platy grains. The presence of this mineral is noteworthy. It has probably been derived directly from some Pre-Cambrian complex, for the only record from Lower Palaeozoic rocks is that of Mr. W. F. Fleet from the Upper Llandovery of the Midlands.[2]

Chert is often seen as small rounded fragments, no doubt derived from some pre-existing sediment. Quartzite grains are common, consisting of a fine-grained mosaic of angular quartz. Vein quartz occurs in the sandstone masses in D_1, and in a sandstone band in S_2 (*d*). The pebbles range up to 2 cm. in diameter.

Ripple Marks occur in many of the sandstone bands of S_2 (*d*). They are of two kinds—symmetrical and asymmetrical. The former all appear to trend in a north and south direction, and were no doubt formed by wave action in shallow water. Dr. E. M. Kindle considers that symmetrical ripple marks trend approximately with the shore off which they were formed (op. cit., p. 53). These ripple marks at Sodbury therefore confirm the shore-line direction given by Dr. Vaughan.[3]

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[1] *Proc. Bristol Nat. Soc.*, ser. IV, vol. vi, 1925, part iii, p. 242.

[2] GEOL. MAG., Vol. LXII, 1925, p. 104.

[3] *Rep. Brit. Assoc. Manchester*, 1915, p. 430.

V. CONDITIONS OF DEPOSITION AND POSSIBLE SOURCE OF THE DETRITAL MINERALS.

The Old Red Sandstone period ended with a marine transgression, the Avonian sea in *Cleistopora* times being shallow and depositing calcareous and argillaceous sediments together with a good deal of sandy material. No doubt the rivers which had been initiated n Devonian times still brought down detrital material. The imestones must represent the material deposited from clear water, though the intercalated bands of shale show that there were frequent incursions of mud.

By the commencement of *Zaphrentis* time further subsidence had taken place, the beds being on the whole remarkably free from detrital matter. At this time the shore-line of the Avonian sea was farthest removed from our area. Towards the top of this zone the beds contain an increasing amount of terrigenous material, and they are followed by the *laminosa*-dolomite and *Caninia*-oolite, ndicating a progressive shallowing of the sea. The latter beds often show marked current bedding.

In C_2 the rocks indicate the commencement of " *Modiola*-phase " conditions. They consist mainly of calcite mudstones, which pass up into more sandy beds in S_1. At the top of this sub-zone a massive band of sandstone indicates the proximity of land and probably represents a lenticular deposit such as a sandbank, as no sandstone occurs at this horizon in the quarries a short distance to the north.

After a temporary deepening of the sea, shallow water conditions were again established in early S_2 times until another " *Modiola*-phase " is marked by the sandstones and shales of S_2 (*d*). The evidence afforded by ripple marks, etc., shows that the beds were deposited in water so shallow that exposure to subaërial conditions occasionally took place. We may postulate in-shore conditions, near a land of low relief.

In D_1 standard marine conditions again resulted in the deposition of foraminiferal and oolitic limestones. As previously mentioned, the latter are exceptionally free from detrital material. This purity does not support the suggestion of Professor Skeats that " a chemically pure limestone has been formed under ' coral reef ' onditions ".[1]

The top of the Avonian sequence is not seen, but Sir A. Strahan, n 1902, observed shales approximately on the same strike as the imestone, and he assumed that they were nearly at the top of the ormation.[2] In the Wickwar Ridge to the north of the Sodbury district " Millstone Grit " conditions were established at the op of S_2.[3]

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[1] *Q.J.G.S.*, vol. lxi, 1905, p. 111.
[2] *Mem. Geol. Surv., Summary of Progress for 1902*, p. 194.
[3] Dr. F. S. Wallis, *Proc. Bristol. Nat. Soc.*, ser. IV, vol. iv, 1923, pt. i, p. 73.

The mineral assemblage of the Sodbury rocks suggests derivation in part from a metamorphic complex of acidic rocks, for strained quartz and mica are abundant. The grains are all of the more stable minerals which would persist when carried a long distance, or through more than one cycle of sedimentation.

All that can be said is that the mineral suite has probably been derived, directly or indirectly, from some Pre-Cambrian complex to the north or north-west.

VI. Summary and Conclusions.

(*a*) The insoluble residues from the limestones contain detrital quartz, amorphous, cryptocrystalline and microcrystalline silica, siliceous pseudomorphs after organic remains, sponge spicules, fluor, magnetite, pyrites, zircon, ilmenite, tourmaline, muscovite, biotite, and felspar.

(*b*) No megascopic chert occurs.

(*c*) The succession contains more arenaceous and argillaceous rocks than occur in the Avon section. They contain magnetite, rutile, zircon, ilmenite, tourmaline, muscovite, and staurolite among the rarer constituents

(*d*) Oolites have a notably small average percentage of insoluble residues, probably owing to their rapid formation, in clear water.

(*e*) The detrital material in the Avonian rocks of Sodbury has probably been derived, directly or indirectly, from some Precambrian complex to the north or north-west.

In conclusion I wish to thank Mr. H. L. Sargent for examining several of my silica residues, Professor S. H. Reynolds, and Dr. S. Smith for much kind help and criticism, and Dr. F. S. Wallis, whose ready aid has been invaluable in the identification of the heavy minerals.

VII. Bibliography.

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1905. Vaughan, *Q.J.G.S.*, vol. lxi, pp. 204–11, and vertical section, pl. xxvii.
1923. Reynolds, Geol. Mag., Vol. LX, pp. 111–19.
1925. Tuck, *Proc. Bristol Nat. Soc.*, ser. iv, vol. vi, pt. iii, pp. 237–49.

Ranina trechmanni, a new Cretaceous Crab from Jamaica.

By Thomas H. Withers, F.G.S.

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(PLATE VII.)

ONLY a single crab (*Carcineretes woolacotti* Withers, *Ann. Mag. Nat. Hist.*, ser. ix, vol. x, 1922, p. 535, pls. xvi, xvii; vol. xiii, 1924, p. 91, pl. iv, figs. 1–4) has so far been described from the Cretaceous rocks of Jamaica. Remains of this crab have been found in the upper part of the Rudist Limestone both at Logie Green and Trout Hall, near the Rio Minho River, Central Jamaica. Dr. C. T. Trechmann, F.G.S., has now discovered a second species of crab, *Ranina trechmanni* n. sp., and this was found in the shales some 40 feet below the Rudist Limestone between Cambridge and Catadupa, West Central Jamaica. The Rudist Limestone is considered by Dr. Trechmann (Geol. Mag., Vol. LIX, 1922, p. 505; Vol. LX, 1923, p. 345; Vol. LXI, 1924, p. 393) to be of Maestrichtian age, and the shales below, in which the present crab occurs, to be Campanian. This conclusion is borne out by, and to a great extent based on, the evidence of the Cephalopods described by Dr. L. F. Spath (Geol. Mag., Vol. LXII, 1924, p. 28) from the shales underlying the Rudist Limestone at Providence, Port Antonio, Eastern Jamaica, and considered by him to be of Upper Senonian and Maestrichtian age. Professor H. L. Hawkins, however, from a study of the Echinoids (Geol. Mag., Vol. LX, 1923, p. 215) does not agree that these rocks are so high in the Cretaceous as the Campanian or Maestrichtian, and considers that they have a time range from the base of the Upper Cretaceous to about the base of the Senonian.

One cannot base any stratigraphical conclusions on *Carcineretes woolacotti*, for it is an entirely new crab, its family even being uncertain. It does, however, represent the earliest crab in which the last pair of legs are known to be adapted to form swimming-paddles, and it is so essentially modern that it might even have been regarded as of Tertiary age. The second crab, *Ranina trechmanni*, so far as it is preserved, seems to be referable to the genus *Ranina* rather than to the Cretaceous genus *Raninella*. If it is correctly so referred, it represents the earliest occurrence of *Ranina*. Taken together, the evidence of the crabs is therefore not against that late Cretaceous age for these Cretaceous beds which has been inferred from the Mollusca (including Cephalopoda).

Family RANINIDAE.

Genus Ranina Lamarck, 1801.

Ranina trechmanni n.sp.

Diagnosis.—A Raninid crab with the antero-lateral margins produced into four closely disposed spines, and with the surface along the orbito-frontal and antero-lateral margins raised and folded into lobes which lie at the base of the underlying spines or lobes. Surface almost smooth, and uniformly ornamented with minute, flattened granules and pits, the granules usually forming circlets of four, in the centre of which is a single pit, and between the outer edges of each pair of granules a much smaller pit. No definite furrows marking off the cardiac region.

Distribution.—Upper Cretaceous (probably Campanian), shales with *Roudaria*, *Trigonia*, etc., about 40 feet below Rudist Limestone; railway line between Cambridge and Catadupa, Great River Valley, West Central Jamaica.

Holotype.—The unique specimen (Pl. VII, Figs. 1, 2) collected by Dr. C. T. Trechmann, F.G.S., and presented to the British Museum, registered In. 26011.

Description.—Specimen consisting of a cephalothorax, and, on its ventral surface, an incomplete left cheliped showing its outer surface and consisting of the carpopodite, propodite, and dactylopodite, and one of the remaining thoracic legs from the right side, with the carpopodite, propodite, and dactylopodite preserved. Orbito-frontal region slightly incomplete, and the posterior parts of the postero-lateral borders broken and symmetrically bent downwards to give a falsely truncate appearance to the sides of the posterior end of the carapace.

Cephalothorax elongate-oviod, broadest in its anterior third, about one-sixth longer than wide, moderately convex transversely, width of orbito-frontal margin more than half that of the carapace. Length, slightly incomplete, 32 mm., breadth 27·3 mm. Antero-lateral margins produced into four closely disposed spines, gradually increasing in size anteriorly. Postero-lateral margins with small, close-set tubercles or spines emerging from below the raised upper surface. Orbito-frontal margin slightly incomplete; the base of the outer orbital spine is preserved, and this spine or lobe must have stood out prominently; the base of the upper orbital lobe is also preserved, and there are indications on each side of a deep fissure; front incomplete, but no doubt originally produced into a rostrum. All round the carapace the surface is slightly raised and, in the region of the orbito-frontal and antero-lateral margins, is thrown into lobes which correspond to, and lie at the base of, the orbito-frontal and antero-lateral spines or lobes. The lobe above the outer-orbital lobe is the largest and is separated by a deep notch from that above the upper orbital lobe, and in turn is separated by a shorter notch from the front. Surface uniformly and minutely ornamented with flattened granules with intervening pits, but the granules are not quite so conspicuous in the posterior region; the granules are usually arranged in circlets of four, but sometimes five, and in the centre of the circlet is a comparatively large pit, and between the outer edges of each pair of granules is a single and much smaller pit (see Text-fig.). There are no definite grooves or furrows, but the granules do seem to arrange themselves indistinctly into two semi-circular lines to mark off the cardiac region. Branchiostegites with a groove close to the lower margin, limited above by a slight ridge, while a more prominent ridge extends along the middle of the plate; an irregular line of small tubercles is situated just above the slight ridge, and another along the more prominent ridge, and two further irregular ines, rather closer together, below the fourth antero-lateral spine. Sub-orbital lobe short and rounded, marked off by a deep groove.

Cheliped of the typical Raninid type, with the carpopodite moderately long, triangular in shape, with a wide basal articulaion for the propodite, on to which the carpopodite extends. Carpopodite with the upper surface grooved, the inner upper margin having a row of seven equal-sized spines, followed by a arger spine terminating the distal end, the outer upper margin with small closely arranged low spines. Propodite with the upper urface bearing a number of irregularly spaced and prominent spines; four are prominent and equal, and are situated on the outer margin with three smaller spines in a transverse row at the distal end near the articulation with the dactylopodite; below the spines on the outer margin are two alternating rows of small tubercles. Towards the distal end of the lower margin of the propodite are two large distally directed spines. Immovable inger with a strong tooth near the middle, and a low tooth behind it.

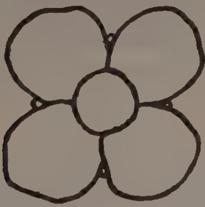


Fig. 1.—*Ranina trechmanni.* Ornament of surface. × 25 diam.

Dactylopodite with its upper surface flat and the upper margins square-edged; along the margins are a number of closely arranged tubercles or short spines, and near the inner margin on the proximal half the upper surface has a line of four larger distally directed spines. A strong low tooth is situated near the articulation with the propodite, followed by four or more low blunt teeth.

Thoracic leg much flattened laterally, the carpopodite long and narrow, the propodite short and broad, somewhat rectangular, and the dactylopodite ovate.

Comparison with other species.—The general form of the carapace and the mode of articulation of the carpopodite and propodite of the cheliped are sufficient to show that the crab belongs to the family Raninidae. In the absence of other parts, its broadly oval carapace and the form of the cheliped seem in more close agreement with *Ranina* s.str. rather than with the Cretaceous genus *Raninella* Brocchi (*ex* Milne-Edwards MS.). From the Cretaceous species, and indeed from all the known species of the family, it is differentiated by the granulated surface being folded into lobes which lie at the bases of the lobes and spines of the orbito-frontal and antero-lateral borders, and by the peculiar ornament. Our knowledge of the appendages of many of the fossil species is insufficient to make a close comparison with this form profitable.

EXPLANATION OF PLATE VII.

RANINA TRECHMANNI n.sp.

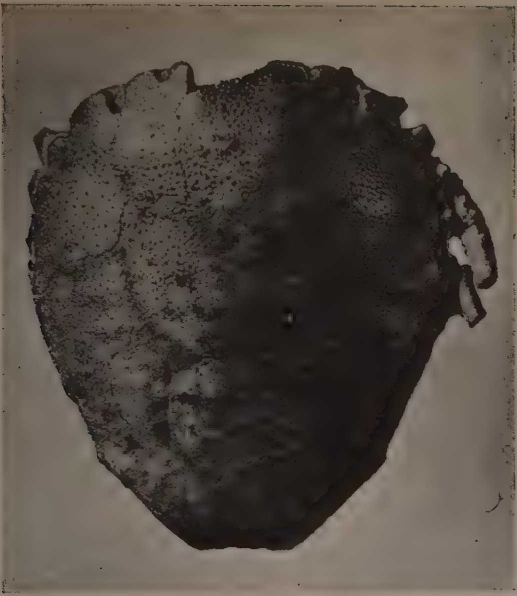
FIG. 1.—Cephalothorax. Outer view. × 2 diam. Brit. Mus., In. 26011.
FIG. 2.—Ventral view of same, showing left cheliped and right thoracic leg.

REVIEWS.

A TREATISE ON SEDIMENTATION. Edited by W. TWENHOFEL. pp. 661, 35 plates. London: Ballière, Tindall, and Cox, 1925. Price 34*s*.

IT is not easy, even after careful perusal, to decide the standpoint from which this work should be judged. As a textbook for students of American sediments, it leaves us with the impression that a more judicious selection of material would have been desirable. That it is not intended as such is indicated by the events which led to its production; moreover, the field that it attempts to cover and the large number of references to textbooks and original papers are in conformity with this view. Therefore we are led to the conclusion that it must be regarded as an attempt to summarize the existing state of knowledge of various aspects of sedimentation, that is, to be a work of reference, from which we may learn in what directions investigation or re-investigation is desirable. A project of this nature is ambitious, and he would be a bold man who would attempt it singlehanded. There is little doubt that the course adopted by our American colleagues was the right one. A committee of the National Research Council, each member being interested in one or more particular branches of the study, planned the compilation of the Treatise and an editor co-ordinated the various contributions. The task of the editor might well be difficult and thankless, with such gaps as might be left for him to fill. In the present "Treatise", with certain clearly-marked exceptions, it is not easy to determine how much is Professor Twenhofel's work, and how much is that of his colleagues. Criticism must, therefore, be general.

The recently published reports of the Committee included the outlines of some useful and suggestive papers, and thus led sympathetic workers to expect much from the Treatise when completed. Those pleasant anticipations have not been altogether realized, but in fairness one must remember that it was not intended to include new material in the Treatise. When we are provided with 640 pages of text and some 1,700 footnote references, it would seem ungracious to emulate Oliver Twist, yet we are



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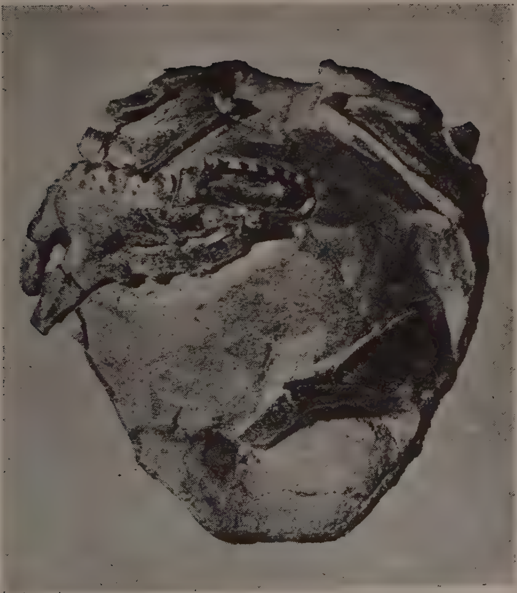

2

H. G. Herring, photo.

CRETACEOUS CRAB (*RANINA*).

[*To face p. 180.*

impressed by the relatively small number of references to extra-American literature. A rough census shows that nearly 70 per cent. of the references are to American textbooks and papers, and rather more than 30 per cent. are to work done elsewhere in the world. Were it not for the praiseworthy reviews of existing literature by David White and E. M. Kindle in their respective contributions, the proportion of American references would be even greater. With all our admiration for the work of distinguished investigators in America, we cannot overlook the fact that the study of stratigraphy, the coining of rock-terms, and the investigation of present-day deposits began on this side of the Atlantic.

The statement in the Introduction that no pretentions are made to completeness disarms criticism, but if treatment is selective, then readers may reasonably expect it to be judicious and fair, fair to the subject and fair to the earlier investigators. Readers of the Treatise will have no difficulty in deciding whether the selection is satisfactory or not. Needless to say, in a book of more than 600 pages, a large amount of information has been presented.

A discussion of the Treatise section by section, taking note of omissions and errors, would occupy a whole number of the GEOLOGICAL MAGAZINE. In making a selection, then, due care must be exercised in the hope that the criticism offered, based as it must be on examples, will at least bear the stamp of impartiality. Let us at once say, then, that Dr. David White's summary of carbonaceous deposits (chapter v) is good; similarly, Professor W. A. Tarr's account of chert, flint, concretions, etc., covers most of the field (with a distinct American bias), and Mr. Kindle's contribution on ripple-marks and other structural features (chapter vi) is, as we should expect, comprehensive. Of the remainder, the treatment of calcareous sediments and of deposits due to the agency of animals (chapter iv) is perhaps the best.

In chapter i (Sources of Sediments) the treatment of laterites (no reference being made of Fox's bibliography) and of the decomposition of rocks and minerals can hardly be regarded as adequate. The same may be said of the sections on transport and water-sorting generally in chapter ii, although here it is difficult to know when to stop. We are surprised to be told in connexion with fall of particles that in the case of water the decrease of viscosity with rise of temperature is not important. No mention of Sherlock's compilation is made in the portion dealing with Man as a geological agent. The discussion on cementation and induration of sediments covers a small part of the field.

Chapter iii is concerned with topographic and climatic control. While much useful information has been gathered together, the authors cannot be congratulated on their selection of examples from Europe. Much of the classic work on the types of deposits described is not referred to. A wider acquaintance with black shales and with graptoliferous sediments in general might perhaps have led the authors to express their views on pp. 129 and 200 with more caution.

Chapter v (Products of Sedimentation) comes near to being a discussion of the petrography of sediments. The references to work on mechanical analyses are few and arbitrary, and it is surprising when we remember the elaborate and important detailed work done in many parts of Europe to find that the only two papers cited on the composition of pebble-beds are those in the Proceedings of a local British Society. As an example of the kind of statement so frequently found in this book, due doubtless to a limited acquaintance with the subject, we may quote the following: "The constitution of sands has received little attention in America, and most of the published work is that of English students on English formations." In point of fact, British (not English) students having been late in the field, number only one-third of the list of investigators. Elsewhere we read: "In addition to these commoner minerals, there is a considerable number of relative unimportance in igneous rock, which persist because of their durability. These yield valuable evidence relating to the sources of the sediments. Zircon, rutile, apatite, andalusite, staurolite, ilmenite, topaz, and monazite are those most important." Loose thinking and writing are evident here. The list is not happily chosen from the point of view of igneous rocks, it does not include the most important, and many of those cited are far from durable.

Space prevents reference to the numerous other instances to which attention might be drawn. We can only mention outstanding omissions such as that of any reference to the Royal Society's Report on Funafuti (the spelling of which, by the way, is varied on different pages of the Treatise) either in the sections on coral reefs, the work of organisms, or the formation of aragonite and dolomite; or to recent French work on the genesis of iron ores. Reference to European geological surveys include only about eight in all, to those of Britain (3), France (1), Switzerland (3), and Prussia (1). Only four of the great oceanographical expeditions are mentioned, and there are but two references to the valuable Monaco publications.

In the section on felspars, the authors have contented themselves with reproducing some of the matter from an American paper that is manifestly incomplete in its treatment and references. They are obviously unacquainted both with the literature and with the work already accomplished.

The contributions by Messrs. Kindle and Tarr in chapter vi (Textures, Structures, etc.) have been mentioned above. We will here only point out that spherulites are not referred to, except at second-hand through Bucher's paper, in which they receive but little consideration.

Chapter vii (on Environments), though speculative, is interesting and suggestive.

It would have been an advantage if much of chapter viii on Field and Laboratory Studies, which completes the book, had been omitted entirely. Laboratory methods of investigation of sediments are more appropriately left to textbooks of petrology, and the Treatise is not intended as such. In the very sketchy account of mechanical analysis, reference is made to two publications; one of these is a small textbook which does not deal with the subject, the other is a paper concerned with graphical representation, but not with new technical methods. The half-page account of mineral analysis might as well have been omitted. A prolix account of specific gravity determination occupies more than five pages, and includes a description of a modification of the pyknometer method, such as is frequently used. This is wholly disproportionate (if not out of place); less space, for example, is devoted to the occurrence and significance of felspars as authigenic constituents in rocks.

The practice of quoting at second- or third-hand from textbooks is not desirable, for it suggests that the authors have avoided the trouble of consulting the original papers. The indebtedness of the Treatise to Professor Grabau's *Principles of Stratigraphy* is obviously very great.

We find in this book no reference to the work of Judd, either n connexion with the Nile delta, the Funafuti report, or the British Jurassic sediments, nor do we see any citation of the work of J. A. Phillips, Watts, Marr, Lapworth (whose eye for minute ithological differences was admittedly so keen); similarly, no mention is made of the names of van Baren, Cullis, Delesse, Dubois, Ehrenberg, Gilligan, Gregory, Hickling, Hummel, Issel, Lamplugh, J. de Lapparent, Ledoux, Meunier, Ramann, Rastall (separately), Retgers, S. H. Reynolds, Richards, Steinmann, Strahan, Herbert H. Thomas, Tschirvinsky, Vernadsky, Wetzel, W. H. Wheeler, and a host of others.

With this book in front of us we have almost to resist an attempt at proof-correcting, for we note inaccuracies in the initials or pelling of Arzruni, Atterberg, E. B. Bailey, Brazier, Buchanan, Chrustschoff, Craig, Crosfield, G. F. Deacon, Dixon, Foullon, Free, . H. Goodchild, Guppy, Jamieson, Kaufmann, Lacroix, Molen-raaff, Monckton, Peach, Ramsay, Schwarz, Stamp, Termier, nd others. Guppy, for example, appears as Gruppy in the text nd Cruppy in the index, and the student is not helped by a eference to his paper in the *Scottish Geol.* (*sic*) *Magazine*. There is little excuse for different spellings of the same name on different ages, especially when none is correct. A considerable number of rinter's errors remain uncorrected and the index requires revision. The use (or non-use) of accents in references to literature can only e described as free and easy, and the expressions Comptes Rendu nd Compte Rendus are frequent. To emphasize such small, but umerous, errors may savour of quibbling, but it has rightly been aid that the man of science who cannot be accurate is beyond redemption. In any case, a writer who does not take the trouble to state authors' names correctly can scarcely command the reader's confidence in the accuracy of his accounts of their work.

In fine, many parts of the Treatise lack accuracy and thoroughness. If the work is not intended to be thorough, then the authors cannot all be congratulated on their selection of material or references. If, on the other hand, it is to be a starting-point for new investigations, we feel constrained to urge intending researchers to read up their subjects for themselves. To British students the price of the book seems unduly high.

P. G. H. Boswell.

THE WILDERNESS OF SINAI, a record of two years' recent exploration. By H. J. LLEWELLYN BEADNELL. With a foreword by D. G. HOGARTH. pp. xvi, 180; 20 plates, 3 maps, 1 section. London: E. Arnold and Co., 1927. Price 10*s.* 6*d.* net.

THIS work contains two short chapters dealing with the geology of the country, and the reproductions of photographs give an excellent idea of its striking physical features.

THE AGE OF THE EARTH. By ARTHUR HOLMES. pp. 80. (Benn's Sixpenny Library, No. 102.) London: Ernest Benn, Limited, 1927. Price 6*d.*

THE aim of this new series is to provide "a reference library to the best modern thought, written by the foremost authorities, at the price of sixpence a volume." In the volume before us the publishers have certainly succeeded in their highly commendable enterprise. Readers of this Magazine will expect a work written by Professor Holmes on the age of the earth to be both authoritative and attractive, and they will not be disappointed.

THE GEOLOGY AND PALAEONTOLOGY OF THE KAISO BONE-BEDS. I. GEOLOGY. By E. J. WAYLAND. II. PALAEONTOLOGY. By A. T. HOPWOOD, W. E. SWINTON, E. I. WHITE, L. R. COX. pp. 71, 2 maps, 9 plates. Uganda Protectorate, Geological Survey Department, Occasional Paper No. 2, November, 1926.

THIS memoir gives the results of the Percy Sladen Expedition to Lake Albert in 1924. The Kaiso Bone-beds form the plains on the eastern side and southern end of Lake Albert, and also occur in the depressions of Lakes George and Albert. The deposits are essentially clays, with some arenaceous beds, and are of shallow water origin; their thickness is at least 1,000 feet, and bone-beds occur at several horizons. The deposits apparently rest on a floor formed of the same rocks as the neighbouring escarpments—an ancient crystalline complex, and sedimentary rocks which are probably pre-Cambrain.

The mammals include *Machairodus* ?, *Rhinoceros*, *Hipparion*, *Equus zebra*, a Chalicotherid, *Sus*, *Hylochoerus*, *Hippopotamus*, and two species of *Elephas*. They indicate a late Pliocene age and, although typically African, the presence of a second elephant and of *Hipparion* gives signs of outside influence, possibly indicating a connexion with the East through Asia Minor. The new species of *Hippopotamus* seems to furnish a link with the Pleistocene of Madagascar.

The Reptiles belong to the genera *Testudo*, *Podocnemis*, and *Crocodilus*, and have Egyptian and East African affinities.

The Molluscan genera represented are *Viviparus*, *Tiara*, *Cleopatra*, *Aetheria*, *Unio*, *Mutela*, and *Pliodon*. This fauna is more varied than that now living in Lake Albert, and many of the species attained larger dimensions than the corresponding living forms.

REPORTS AND PROCEEDINGS.

Glasgow Geological Society.

13th January, 1927.

(*a*) " Further Data regarding the Kainozoic Dykes of the Clyde Region." (*b*) " Contribution to the Petrography of the late Palaeozoic Igneous Suite of the West of Scotland." By Dr. G. W. Tyrrell.

(*a*) The Kainozoic basic dykes of the Clyde region are not uniformly distributed ; in some places they are scarce, in others abundant. The dyke-swarms of the West of Scotland occur in two main bundles trending south-east. The more northerly originates in Mull, the more southerly in Jura, whence it passes through Arran, where the trend changes direction to south–south-east. To this bundle belong the dykes of the Clyde region, with Arran as the centre of distribution. In Arran the dykes belong to four groups, associated with four distinct volcanic episodes—(1) Intrusion of the great crinanite sills of the south-east quadrant of the Island. (2) Intrusion of quartz dolerite. (3) Intrusion of the northern granites. (4) The final phase of activity. The majority of the dykes are associated with the last, and cut all the others. The clefts which the dykes of the Clyde region occupy are oriented at right angles to a north-east–south-west direction of tension, and are concentrated about the volcanic centres. The large solitary dykes of southern Scotland and northern England, similarly oriented to those of the west coast, are probably connected with another episode. Petrologically these dykes of the Clyde region belong to two series, an undersaturated and an oversaturated, represented respectively by crinanite and tholeiite. The potash content is the criterion for differentiating the Kainozoic and Palaeozoic crinanites. In Mull, according to Bailey and Thomas, there were three resurgences of crinanite, or plateau–basalt, magma ; in Arran, Dr. Tyrrell records two. In the sequence of intrusion representatives of the undersaturated series precede those of the oversaturated series.

(*b*) The late Palaeozoic Igneous Suite of the West of Scotland occurs in two areas—round Mauchline and in Nithsdale. The present paper deals only with the Mauchline area. The igneous rocks there form a ring-shaped outcrop. They lie in a basin of the Barren Red Measures, and are overlain by the New Red Sandstone of Ballochmyle. The lavas are slaggy and scoriaceous. Their thickness, inclusive of thin sandstones and tuffs, is estimated at 300 feet. Basaltic detritus occurs at the base of the overlying sandstone. Similar basaltic detritus has been found at the same horizon in Arran. The Mauchline lavas were poured out from about sixty vents of " Greenhill " type. Dr. Tyrrell described a number of these, particularly the composite vent of Carskeoch Hill, the sequence of intrusion there being (1) Agglomerate, (2) Plug of monchiquite, etc., (3) Essexite dolerite. The petrography of the suite shows that a number of types are present. (1) Olivine basalt (Dalmeny type + analcite), (2) Analcite basanite (Hillhouse type, richer in analcite), (3) Limburgite, nepheline basanite, monchiquite, bekinkinite. Compared with the lavas of the Lower Carboniferous the suite is richer in alkalis, poorer in SiO_2, and more basic. It represents the final phase of Carboniferous volcanic activity, and is therefore more differentiated and specialized.

10*th February*, 1927.

" The Physiography and Geology of Morvern." By J. F. Scott, B.Sc.

The area is bounded by Loch Sunart and Glen Tarbert, Loch Linnhe, and the Sound of Mull. These boundaries involve two sets of geographical lines—north-west–south-east and north-east–south-west. The Sound of Mull and the eastern part of Lake Sunart (with Glen Tarbert) trend north-west–south-east, and are consequent river valleys, with no relation to the grain of the country Loch Linnhe, which is part of the Great Glen, and Loch Shiel with the middle part of Lake Sunart trend north-east–south-west, and are subsequent. Where the Lake Shiel–Lake Sunart fracture-zone approaches the Morvern coast three diverging faults are developed. The most important of these takes a westerly trend, and, cutting through Carna, skirts the coast of Morvern to Auliston Point. Further faulting in the area has a general direction varying between north–south and north-east–south-west, and is often responsible for the preservation of Mesozoic strata.

The general trend of the ice-flow over Morvern was north-east–south-west in the north, and almost due west in the southern and south-western parts, these directions being almost at right angles to the great Arienas-Teacuis valley.

The geology was illustrated principally from outcrops occurring within Sheet 52 (Scot.). The Moine Gneiss has a strike of foliation approximately north–south, and is typically well-banded. The great Morvern granite is of two varieties (pink and grey), and has an outcrop of about 80 square miles. The basal bed of the Trias is either a breccia or a cornstone, and in the latter case the association with the underlying Moine is very intimate. Liass is represented by fossiliferous Broadford beds, and by Pabba shales, generally unfossiliferous. Cretaceous comprises in ascending succession highly glauconitic greensand and fossiliferous greensand, white desert sandstone, and silicified chalk. The Kainozoic lavas have a thickness of over 1,300 feet.

Edinburgh Geological Society.

22nd December, 1926.

" Some Geological Notes on the Volcanoes of Hawaii." By A. M. Cockburn, B.Sc.

The Hawaiian Archipelago, nearly 1,800 miles in length, is situated along a line of earth weakness. Vulcanicity appears to have commenced on the north-west and travelled south-eastwards along this line. Active vulcanicity is now confined to the island of Hawaii; the most south-easterly member of the group, Mauna Loa, 13,675 feet, and Kilauea, 4,040 feet, being the two foci of eruption.

A short account of the faulted " crater " Haleakala, Maui, and a summary of the history of Kilauea since it was first known to white man early in the nineteenth century were given. Igneous phenomena within and around Halemaumau were noted, including accounts of fountaining, ascent, and descent of the lava within the pit. Lava tubes, spatter cones, the spinning of Pele's Hair, etc., were described. The canals around Halemaumau, first noted by Coan in 1884, and investigated two years later by Lyman, were described, and it was shown how Lyman came to the conclusion that the general level of the floor of the pit had been raised over a hundred feet in two years.

The sounding of Halemaumau in 1917, by means of steel pipes, proved that there were only some forty-five feet of highly fluid lava which rested on a pasty floor. Dr. Jagger introduced the terms " Lake magma " and " Bench magma " for these two lava phases. This discovery gave meaning to the hitherto unexplained appearance, movement, and foundering of islands (of bench magma) within the liquid lake (of lake magma).

The highest temperatures recorded were for blowing cones, 1,350° C. in the air zone of free oxidation. The surface temperature of the molten lake was about 1,000° C. The temperature of the lava just below the surface was 100° C. lower, but rose again to between 1,100° C. and 1,200° C. in the neighbourhood of the " Bench Magma ".

19*th January*, 1927.

(1) " Metasomatism in Basalt, near Eel Burn, North Berwick." By T. Cuthbert Day.

The Eel Burn flows into the sea rather more than a mile west of North Berwick harbour. Just to the east of Eel Burn and extending for half a mile, there is exposed on the shore an irregular outcrop of basaltic lava of the " Markle " type. This rock is found in fresh condition close to the neighbouring residence called " Carlekemp ", but on the shore, near Eel Burn, the basalt has been extensively modified by infiltration of silica, which has replaced the original constituents of the rock, till the silica content has attained 81 per cent., the normal amount being 47 per cent. Within the same narrow area, some of the vesicular basalt has been greatly altered by secondary replacement with carbonates to the extent of 35 per cent., during which process the amount of the previously acquired silica has been reduced to 40 per cent.

(2) " An old Hone-stone Quarry near Ratho." By T. Cuthbert Day and David Tait.

The quarry has been long disused ; it lies a short distance to the west of Ratho Hall, within the area of the large quartz-dolerite sill. It contains distinct bands of clay and sandy clay sediments lying horizontally. These have been altered to some extent by contact with the igneous rock, which lies along the top of the quarry. They are not at all hard, and present a spotted appearance ; while certain of the less sandy layers of the rock were once valued as a source of hone stones. Specimens were collected and analyzed, and compared with the well known Water of Ayr stone, which they resemble much in appearance. The peculiar abrasive quality appears to depend on the presence of a considerable amount of secondary isotropic silica.

(3) " The Lower Limestones and Associated Volcanic Rocks of a Section of the Fifeshire Coast." By George A. Cumming, B.Sc.

Six Marine Limestones occur on the East Fifeshire coast between Elie Ness and Chapel Ness, Earlsferry. The lowest of these is nearly in contact with a dolerite intrusion in Woodhaven. The proximity of this mass has resulted in almost complete recrystallization of the limestone with consequent destruction of all organic remains. From the great thickness of the seam, exceeding that of any of the other limestones visible in the section, it is inferred that this is the " White " or Hurlet Limestone of St. Monans. The highest of the marine limestones is immediately overlain by the Edge Coals, exposed at Earlsferry. There is, therefore, in this section, a complete exposure of the Lower Limestone Group.

The sedimentary rocks are pierced by three volcanic necks. A small vent in Woodhaven is comparable to the Explosion Fissure to the east of the Rock and Spindle, St. Andrews. This orifice is filled with a breccia of sandstone and shale. The agglomerate at Elie

Harbour entirely surrounds a mass of sediment hitherto regarded as a partition wall, projecting between two contiguous necks. This agglomerate is therefore now considered to belong to one neck in which a large mass of sedimentary material has been enclosed. A small vent pierces the Earlsferry Coals. The material of this neck is peculiar, consisting mainly of basalt and "White Trap."

Several crystals of zircon in the agglomerate at Elie Ness verify the discovery of zircon at this locality by Traill, mentioned in Heddle's *Mineralogy of Scotland.*

A boulder of glauconitic sandstone containing Lower Greensand fossils was found in the Arctic Shell-bearing Marine Clay in Woodhaven.

OBITUARY.

Charles Doolittle Walcott, LL.D., Sc.D., Ph.D.

BORN 31ST MARCH, 1850. DIED 8TH FEBRUARY, 1927.

The death of Dr. Walcott has deprived us of one of the world's leading geologists who, having made his first geological excursion in his thirteenth year, had pursued the study of the science for sixty-four years. Although occupied during a large part of his life with important administrative work, this did not prevent him from carrying out researches of the highest value.

In 1876 Walcott was appointed assistant to Professor James Hall, the State Geologist of New York, and three years later became Assistant Geologist on the United States Geological Survey. In the ensuing years he did much field work, particularly in the Western States. In 1888 he was appointed palaeontologist to the Survey, with charge of the invertebrate fossils, and in 1894 Director of the Survey. This post he held until 1907, when he obtained the "blue ribbon" of science in the United States, being made Secretary of the Smithsonian Institution.

During his latter years Walcott devoted special attention to the organisms of the Algonkian and Lower Palaeozoic rocks, more particularly to the sequence of the Cambrian faunas of the States and Canada. In his last years he visited, season after season, the mountain region of British Columbia, establishing a detailed sequence of the various faunas and describing the characters of the principal organisms. His work on the Trilobites and their allies and on the Brachiopods is particularly noteworthy. Walcott's masterly monograph on the Cambrian Brachiopoda appeared in 1912; and year by year he issued memoirs on the Trilobites and other fossils. Many of these were preliminary to further studies, but he has left a mass of material for use by those who have been trained by him.

We may specially refer to his monograph on *The Fauna of the Lower Cambrian or Olenellus Zone*, 1890, and to the large series of memoirs on *Cambrian Geology and Palaeontology*, writings of high importance and embodying the results of a prodigious amount of work.

It was fortunate that Walcott was able to pursue his detailed studies on the Mt. Stephen formation of British Columbia, one horizon in which may well be described as the " Solenhofen slate " of the Lower Palaeozoic period, so beautifully are its organisms preserved, and the work thereon will be of incalculable benefit to geologists and biologists alike.

Walcott was a man of commanding presence and magnificent physique. His friendship was a possession of which to be proud. He was a genuine lover of nature, evidence of which is furnished both by his published works and his private correspondence. In the study of the Cambrian System he forms one of a great trio—Sedgwick, Barrande, Walcott, and his name will ever be enrolled in the list of the world's great geologists.

J. E. M.

Leslie D. Currie, B.Sc.

BORN 19TH APRIL, 1904. DIED 9TH NOVEMBER, 1925.

We regret to announce the death of Leslie D. Currie, who was drowned while bathing in Burma. Mr. Currie, after a brilliant career at Glasgow University, had just joined the staff of the Burma Oil Company as palaeontologist. After completing his degree he spent twelve months on research work on some undescribed Crustacea from the Silurian rocks of Lesmahago. A paper on a new Xiphosuran is published in this MAGAZINE, but his main work on another series was still incomplete. By his death palaeontology has lost a very promising worker.

J. W. G.

CORRESPONDENCE.

THE GEOLOGY OF THE WEST INDIES.

SIR,—Much as I appreciate Dr. Wayland Vaughan's recognition of my work in the Leeward Islands between 1920 and 1923, in two of his recent papers,[1] I feel I cannot allow some of his criticisms to pass unchallenged.

In the first paper, Dr. Vaughan tabulates some fifty igneous rock specimens from Antigua, St. Bart's, St. Martin, Anguilla, St. Kitts, St. Croix, and St. Thomas, as determined by the late Professor J. P. Iddings.

As I expected, Dr. Vaughan is inclined to quarrel with my contention of a dissimilarity between the Windward and Leeward Islands on the one hand, and the Virgin Islands on the other in their petrological characters. In support of this he cites the occurrence of andesites, dacites and andesitic tuffs, characteristic of the Leeward Islands—in Cuba, St. Thomas, St. Croix, and St. Bart's.

Of these islands, however, St. Croix and St. Bart's belong to the Leeward Island group, as shown by the bathymetric soundings in the neighbourhood of the Anegada channel.

Further, Dr. Vaughan ignores the converse side of the proposition, namely that in only one single exposure [2] has he been able to collect in situ specimens of plutonic and metamorphic rocks from the Leeward Islands comparable with those of the Virgin Islands. After an elaborate survey of the Leeward and Windward Islands from St. Kitt's to Grenada I can safely say that I have not collected a single specimen of a plutonic or schistose rock in situ. It is largely for this reason that I have always doubted the probability of a Tertiary or even of a Mesozoic age for the igneous complexes of the Virgin Islands—Cuba axis, more especially as the folding there exhibited is quite unlike anything developed in the Leeward Islands proper.

The only other point that I would refer to in connexion with the igneous rocks described in Vaughan's paper is the number of dacites cited from the Leeward Islands, as my own collections were singularly devoid of rocks of that type.

With regard to my paper on Anguilla,[3] Dr. Vaughan takes me to task for questioning his section of Crocus Bay. I accept his present explanation that the section is a composite one, compiled from various exposures up the track leading from the beach to the Valley Post Office, and not a continuous one in a cliff face.

The argument as to whether an altered andesitic tuff should be described as a basic igneous rock would be unimportant were it not that the true basal foundation (augite-andesite) of the limestone is to be seen *underlying* the tuffs at Dog I. and I wish sincerely that Dr. Vaughan had visited the latter island, as he would have seen the striking section showing the relationship of the sedimentary strata to the igneous foundation below.

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[1] "Notes on the igneous rocks of the North-east West Indies and on the island of Anguilla," *Journ. Wash, Acad. Sci.*, vol. xvi, 1926.

[2] Viz. Grand Bay, St. Martin.

[3] *Report on the Geology of St. Kitts, Nevis and the Geology of Anguilla*, published by the Crown Agent for the Colonies, 1924.

I am interested to see from the new section that the clays containing lignite and amber were found in situ at Crocus Bay, as my own excavations on the beach proved so unproductive in that respect. I am also glad to see that Dr. Vaughan is now inclined to regard the Anguilla formation as of Langhian (Burdigalian) age.

I was not able to work out my own fossils sufficiently far to obtain a reliable estimate of the age of the beds, but the late Mr. R. B. Newton, who casually looked over my specimens, expressed the opinion that they represented a Miocene assemblage.

Dr. Wayland Vaughan is inclined to doubt the identification by myself and J. W. Spencer of a marked coral limestone, raised high above the sea-level in Anguilla, and unconformable on the Oligocene limestones, indicating to my mind marked uplift of the island in Pleistocene or Recent times. As Dr. Vaughan apparently never visited the locality where I saw the deposit (viz. 2 miles east of Island Harbour), I think I am entitled to stand my ground firmly on this point.

In conclusion, I would express my regret that many of my reports (particularly those on the Windward Islands) were only published as appendices to the official gazettes of the islands concerned, and are therefore very difficult of access to the public in general, while several, such as those on Dominica, Montserrat, and Barbuda never saw the light of day at all. All my West Indian specimens are now housed in the British Museum (Natural History Museum), and one copy of each published report is stored in the library of the Geological Society, London.

K. W. EARLE.

GEOLOGICAL DEPT.,
UNIVERSITY COLLEGE,
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ERRATA ET ADDENDA.

Page 123, *for* Middle Louth Seam *read* Middle Lount Seam. The quartzite pebble described was exhibited at the Geological Society on 22nd April, 1925 (*Proc. Geol. Soc.*, *Q.J.G.S.*, lxxxi, 1925, p. cxxiv), and has since been presented to the Museum of Practical Geology, Jermyn Street.

Page 143, line 9 from bottom, *for* J. P. Paul *read* F. P. Paul.
,, ,, 7 ,, ,, *for* endialite *read* eudialite.
,, ,, 7 ,, ,, *for* Shannon Pier *read* Shannon Tier.